

AD-A259 279



MISCELLANEOUS PAPER EL-92-12

2

US Army Corps  
of Engineers

# EVALUATION OF UPLAND DISPOSAL OF OAKLAND HARBOR, CALIFORNIA, SEDIMENT

## VOLUME I: TURNING BASIN SEDIMENTS

by

C. R. Lee, H. E. Tatem, J. W. Simmers, J. G. Skogerboe  
B. L. Folsom, Jr., R. A. Price, J. M. Brannon, D. L. Brandon, C. L. Price  
D. E. Averett, M. R. Palermo

Environmental Laboratory

DEPARTMENT OF THE ARMY

Waterways Experiment Station, Corps of Engineers  
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

DTIC  
ELECTE  
JAN 06 1993  
S B D



October 1992

Final Report

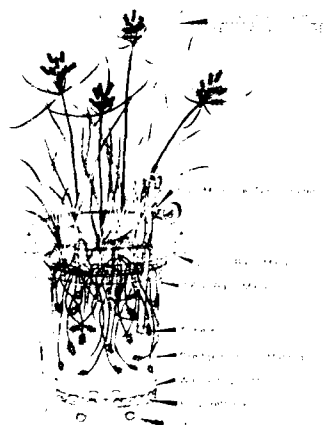
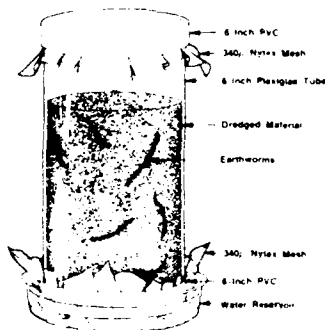
Approved For Public Release; Distribution Is Unlimited

93-00304



Prepared for US Army Engineer District, San Francisco  
San Francisco, California 94105-1905

93 1 05 014



Destroy this report when no longer needed. Do not return  
it to the originator.

The findings in this report are not to be construed as an official  
Department of the Army position unless so designated  
by other authorized documents.

The contents of this report are not to be used for  
advertising, publication, or promotional purposes.  
Citation of trade names does not constitute an  
official endorsement or approval of the use of  
such commercial products.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE October 1992	3. REPORT TYPE AND DATES COVERED Final report (In 2 volumes)		
4. TITLE AND SUBTITLE Evaluation of Upland Disposal of Oakland Harbor, California, Sediment; Volume I: Turning Basin Sediments		5. FUNDING NUMBERS		
6. AUTHOR(S) C. R. Lee, H. E. Tatem, J. W. Simmers, J. G. Skogerboe, B. L. Folsom, Jr., R. A. Price, J. M. Brannon, D. L. Brandon, C. L. Price, D. E. Averett, M. R. Palermo				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)  USAE Waterways Experiment Station, Environmental Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199		8. PERFORMING ORGANIZATION REPORT NUMBER  Miscellaneous Paper EL-92-12		
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)  USAE District, San Francisco San Francisco, CA 94105-1905		10. SPONSORING/MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161. Volume II describes testing and evaluation of sediments from the Inner and Outer Oakland Harbors.				
12a. DISTRIBUTION/AVAILABILITY STATEMENT  Approved for public release; distribution is unlimited		12b. DISTRIBUTION CODE		
13. ABSTRACT (Maximum 200 words)  This report describes testing and evaluation performed by the Environmental Laboratory of the US Army Engineer Waterways Experiment Station on sediment from the turning basin of Oakland Inner Harbor, Oakland, CA. Test protocols from the Corps' Management Strategy for Disposal of Dredged Material were used in the present evaluation to determine the potential for migration of contaminants into effluent, surface runoff, leachates, plants, and animals at an upland disposal site.  Two sediments from the turning basin of Oakland Inner Harbor were tested: a composite sample of cores taken from the surface to 38-ft depth (upper sediment) and a composite sample of cores taken from 38- to 45-ft depth (lower sediment). In addition, two potential disposal site soils were tested: Twitchell Island and 7th Street disposal site.  (Continued)				
14. SUBJECT TERMS  Contaminant migration Contaminated sediments Dredged material		Sediment testing Upland disposal		15. NUMBER OF PAGES 288
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED		18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED		16. PRICE CODE
19. SECURITY CLASSIFICATION OF ABSTRACT		20. LIMITATION OF ABSTRACT		

### 13. (Concluded)

Sediment characterization indicated that the Oakland upper sediment contained higher concentrations of most contaminants than the lower sediment. Metal concentrations in the Oakland lower sediment were in the range of values found at the Twitchell Island disposal site. The Oakland upper sediment contained levels of cadmium and arsenic similar to those in Twitchell Island levee soils, but higher levels of zinc, nickel, lead, and copper. With the exception of nickel, all metal contents in both Oakland sediments were below the maximum levels allowed for agricultural production by the US Department of Agriculture. Oakland sediments contained higher contents of butyltin, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons than both the Twitchell Island levee soil and the 7th Street disposal site soil.

Results from effluent, surface runoff, leachate, and plant and animal bioassay tests indicated the need for some restrictions to be implemented at both the Twitchell Island disposal site and the 7th Street disposal site. The disposal of Oakland sediments at either site can be managed to minimize the impact to the environment associated with each site. Reconditioning of the dredged sediment prior to disposal at Twitchell Island would eliminate the potential for contaminant migration as leachate. Dredging should be conducted in a manner that minimizes the amount of estuarine water transported with the sediment to Twitchell Island for disposal.

Collection and treatment of leachate at the 7th Street disposal site was recommended to reduce the overall contaminant flux in leachate from the disposal operation. Control of suspended solids in effluent and surface runoff was recommended. A mixing zone of 10 to 1 will be required to dilute any contaminant in effluent and surface runoff waters to meet imposed water quality limitation standards. Management of plant colonization was recommended to minimize cadmium migration into the herbivore food chain and to deter colonization by birds and mammals.

If Oakland sediments are used to supplement levee stability and plant growth occurs on these sediments, plant uptake of cadmium will potentially exceed acceptable levels for agricultural production of leafy vegetables and small grains such as wheat. Therefore, plant growth on the levees should be restricted to nonagricultural production. The levees should be planted with grass species that minimize cadmium uptake, such as red fescue. Monitoring of the plant and animal communities that establish at the Twitchell Island disposal site was recommended to verify minimization of contaminant migration into herbivore food chains.

Accession For	
NTIS GRA&I	<input checked="" type="checkbox"/>
DTIC TAB	<input type="checkbox"/>
Unannounced	<input type="checkbox"/>
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

DTIC QUALITY INSPECTED 5



## SUMMARY

Construction of both the Oakland Outer Harbor Deepening Project and the Oakland Inner Harbor Deepening Project were authorized by the Water Resources Development Act of 1986, 99th Congress, 2nd Session, Public Law 99-662. Modifications to the authorized plan were made in 1987 to reduce the amounts of material dredged to 2.8 and 3.7 million cubic yards (2.1 and 2.8 million m<sup>3</sup>) for the Oakland Outer and Inner Harbors, respectively. Sediment testing and evaluation indicated that most of the dredged material was suitable for unrestricted open-water disposal, except for samples collected from the turning basin area of Oakland Inner Harbor. Consequently, other disposal alternatives were evaluated.

The US Army Engineer Waterways Experiment Station was asked to assist in the evaluation of other alternatives for the turning basin sediments, such as upland disposal. Volume I of this report describes the testing and evaluation of the turning basin sediment. Volume II of this report describes the testing and evaluation of sediments from the rest of the project, both Inner and Outer Oakland Harbors. The Corps' Management Strategy for Disposal of Dredged Material was applied to the evaluation. Using this strategy, a sediment is tested and evaluated for potential disposal site environments, including aquatic, wetland, and upland. The test protocols were used in the present evaluation (Volume I) to determine the potential for migration of contaminants into effluent, surface runoff, leachates, plants, and animals at an upland disposal site. These same test protocols were used in a second evaluation (Volume II) to determine the potential for migration of contaminants in sediments from the rest of the dredging project.

Two sediments from the turning basin of Oakland Inner Harbor were tested: a composite sample of cores taken from the surface to the 38-ft (12-m) depth (upper sediment) and a composite sample of cores taken from the 38- to 45-ft (14-m) depth (lower sediment). In addition, two potential disposal site soils were tested: Twitchell Island soil and 7th Street disposal site soil. At Twitchell Island, the dredged sediment would be used to rebuild levees. The 7th Street disposal site would be used to collect, store, and recondition the dredged sediment.

Sediment characterization indicated that Oakland upper sediment contained higher concentrations of most contaminants than the lower sediment. Metal concentrations in the Oakland lower sediment were in the range of values

found at the Twitchell Island disposal site. Oakland upper sediment contained levels of cadmium and arsenic similar to those in Twitchell Island levee soils, but was higher in zinc, nickel, lead, and copper. With the exception of nickel, all metal contents in both Oakland sediments were below the maximum levels allowed for agricultural production by the US Department of Agriculture. Oakland sediments contained higher contents of butyltin, polychlorinated biphenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs) than both the Twitchell Island levee soil and the 7th Street disposal site soil. These bulk sediment chemical analyses indicated a need for further testing of potential contaminant migration pathways, such as effluent, surface runoff, leachate, and plant and animal uptake at the proposed disposal sites.

The evaluation of effluent test results indicated that, with the exception of arsenic, the dissolved concentrations of all contaminants discharged as effluent will meet all water quality criteria. The concentrations of dissolved arsenic will require a dilution of 7 to 1 (upper sediment) or 2 to 1 (lower sediment) in a mixing zone to meet water quality criteria.

The total mass release of contaminants as effluent was estimated to be generally less than 1 percent of the total contaminants placed, and varied with respect to the assumed concentration of total suspended solids (TSS) in the effluent. The placement operation should be managed to reduce the TSS concentration in the effluent to the largest degree practical. This can be accomplished by the ponding of effluent water within toe dikes prior to discharge. The resulting sedimentation of suspended solids should reduce the total mass release of contaminants.

The salinity of the effluent could potentially cause some adverse environmental impacts. A dilution of approximately 10 to 1 would be required to reduce the salinity to less than 2 ppt and should minimize any impacts due to salinity.

Surface runoff test results indicated that potential surface runoff water quality problems during the wet, unoxidized period of upland disposal would be associated primarily with erosion of particulates. Management of the upland disposal site to remove particulates from surface runoff will result in removal of 90 to 99 percent of all contaminants in surface runoff. Only soluble copper concentrations in surface runoff exceeded the US Environmental Protection Agency Marine Water Quality Criteria, and soluble arsenic and mercury exceeded the Receiving Water Limitation Standards imposed on the Port of Oakland by the California Regional Water Quality Control Board.

Consideration of a mixing zone at the discharge point from the upland disposal site and/or further treatment may be required for those soluble contaminants. A mixing zone ratio of less than 10 to 1 (receiving water to runoff water) would be required to dilute contaminant concentrations below required criteria.

However, if surface runoff were discharged into a freshwater environment, salinity could cause some adverse environmental impacts. A dilution ratio of 10 parts freshwater to 1 part runoff will be required to reduce the electrical conductivity to less than 5 mv/cm, which should minimize any impacts due to salinity. The dilution could be accomplished by the mixing of runoff from approximately 10 acres of freshwater, uncontaminated areas with runoff from each acre of dredged material disposal area.

Potential problems in surface runoff from dry, oxidized sediments should occur only from copper, mercury, and zinc bound to the suspended solids. Consideration of a mixing zone or removal of the suspended solids should eliminate the need for further restrictions, particularly with regard to treatment of soluble contaminants. A mixing zone of less than 10 to 1 would be required to dilute unfiltered contaminant concentrations to less than or equal to the Receiving Water Limitation Standards. Establishment of vegetation either by natural succession or by planting will further reduce contaminant concentrations in surface runoff.

The contaminant leaching potential of Oakland Harbor sediment (upper and lower) was evaluated for both the confined disposal facility (CDF) (7th Street disposal site) and the Twitchell Island levee disposal alternatives. Given the characteristics of Oakland Harbor sediments and the rainfall regime in the San Francisco Bay area, chemical concentrations of the first batch cycle leachate provide a reasonable approximation of leachate quality for at least 160 years in any of the disposal scenarios. The levee alternative produced generally greater percolation volumes because of the greater surface area available for precipitation compared to the CDF alternative. Metal concentrations in the interstitial water and first leach cycle did not exceed drinking water standards, but did exceed Effluent Limitation Standards and Receiving Water Limitation Standards imposed on the Port of Oakland by the California Regional Water Quality Board. Results of leachate generation evaluations indicate that implementation of various control measures for the CDF alternative, e.g., varying placement of the upper and lower material in a CDF or a

geomembrane liner with a leachate collection system, will reduce leachate volume and contaminant mass loss from the CDF.

Oakland Harbor sediments should be reconditioned to remove salt prior to placement on levees. Alternatively, Oakland Harbor sediment can be placed upon levees and constantly irrigated with freshwater to remove salt. However, this would also greatly increase seepage volume compared to that observed from normal rainfall. For example, the pore volume of water equivalent to the seven batch leach steps conducted during testing would move through a 1-ft lift of Oakland Harbor (lower) sediment in 3 years based on the permeability of the material. This would result in increased metal and butyltin concentrations in the leachate during conditioning, because of increasing metal and butyltin concentrations in the leachate.

Upper and lower sediments from Oakland harbor, and soils from 7th Street and Twitchell Island, were subjected to a simulated weathering process for use in estimating potential plant uptake of the metals cadmium, chromium, mercury, nickel, and zinc. Sediments and soils were extracted with an organic extract (DTPA, diethyl-trimethyl-pentaacetic acid) that indicates potential plant availability of these metals. The "weathered" sediments were planted with an estuarine plant species, *Sporobolus virginicus*, and the freshwater index plant *Cyperus esculentus*. The plants were grown, harvested, and analyzed for contamination.

The DTPA extraction data indicated that potential mobility into the environment through freshwater plant uptake is greater from air-dried and weathered sediments than from the original, wet anaerobic sediments, especially for cadmium. The plant bioassay data verified the DTPA extraction data by showing increased cadmium uptake in bioassay plants grown under air-dried sediment conditions.

The initial earthworm toxicity tests indicated that the upper and lower Oakland sediments were toxic when unwashed and nontoxic after two and one washings to remove salt, respectively. Colonization by upland invertebrates will begin relatively soon after disposal and some leaching of salt.

The earthworm test results indicated potential bioaccumulation of tributyltin and dibutyltin, PCBs (Aroclor 1254), and PAHs (fluoranthene and pyrene). Cadmium was not bioaccumulated by earthworms exposed to unvegetated sediment. However, with the establishment of vegetation, the disposal site will be colonized by earthworms and other soil invertebrates that predominantly live and feed in the leaf litter produced by the plants. Consequently,

there is some potential for metals such as cadmium to move into plants and through the herbivore food chain but not into insectivores.

No information relating the potential movement of butyltins from soil invertebrates into the terrestrial food web has been found. However, insectivores and small herbivores could be monitored for butyltin content as the site is naturally colonized. Alternatively, the disposal area could be planted with vegetation that deters colonization by birds and mammals.

PCB movement from soil invertebrates to higher organisms such as insectivorous birds does not appear to pose a potential problem. However, no data relating the movement of PCBs in the herbivore food web have been found.

Relatively low levels of pesticides and PAHs observed in earthworm tissues do not indicate the need for any management practices to isolate these compounds from food webs that may become established on the dredged material.

In summary, results from effluent, surface runoff, leachate, and plant and animal bioassay tests indicate the need for some restrictions to be implemented at both the Twitchell Island disposal site and the 7th Street disposal site. The disposal of Oakland sediments at either site can be managed to minimize the impact to the environment. Reconditioning of the dredged sediment prior to disposal at Twitchell Island would eliminate the potential for contaminant migration as leachate. Dredging should be conducted in a manner that minimizes the amount of estuarine water transported with the sediment to Twitchell Island for disposal. Collection and treatment of leachate at the 7th Street disposal site is recommended to reduce the overall contaminant flux in leachate from the disposal operation. Control of suspended solids in effluent and surface runoff is recommended. A mixing zone of 10 to 1 will be required to dilute any contaminant in effluent and surface runoff waters to meet the State's water quality limitation standards.

Management of plant colonization is recommended to minimize cadmium migration into the herbivore food chain and to deter colonization by birds and mammals. If Oakland sediments are used to supplement levee stability and plant growth occurs on these sediments, plant uptake of cadmium will potentially exceed acceptable levels for agricultural production of leafy vegetables and small grains such as wheat. Therefore, plant growth on the levees should be restricted to nonagricultural production. The levees should be planted with grass species that minimize cadmium uptake, such as red fescue. Monitoring of the plant and animal communities that establish at the Twitchell

Island disposal site is recommended to verify minimization of contaminant migration into herbivore food chains.

## PREFACE

This report presents the results of an evaluation of upland disposal of sediment from Oakland Harbor, California, performed for the US Army Engineer District, San Francisco. Project managers at the San Francisco District were Mr. Brian Walls and Mr. Duke Roberts. The study was conducted by the Environmental Laboratory (EL) of the US Army Engineer Waterways Experiment Station (WES). Participants included Dr. Charles R. Lee, Soil Scientist; Dr. Henry E. Tatem, Zoologist; Dr. John W. Simmers, Biologist; Mr. John G. Skogerboe, Hydrologist; Dr. Bobby L. Folsom, Jr., Soil Scientist; Mr. Richard A. Price, Agronomist; Dr. James M. Brannon, Research Chemist; Mr. Dennis L. Brandon, Statistician; and Ms. Cynthia L. Price, Biologist, all of the Ecosystem Research and Simulation Division (ERSD), EL; and Mr. Daniel E. Averett, Research Civil Engineer, and Dr. Michael R. Palermo, Research Civil Engineer, Environmental Engineering Division (EED), EL. The work was conducted under the supervision of Mr. Donald L. Robey, Chief, ERSD; Dr. Raymond L. Montgomery, Chief, EED; and Dr. John Harrison, Director, EL.

The plant portion of the study was conducted by personnel of the Contaminant Mobility Research Team: Dr. Folsom, Team Leader; Mr. Price; and Mr. Keith E. Fessel. Mr. Larry Bird and Ms. Alma Dideaux conducted the laboratory and growth chamber portions of the earthworm bioassessment study. Chemical analyses of sediment, water, and tissues were performed by Dr. Eric Cercelius, Battelle/Marine Sciences Laboratory, Sequim, WA. Sediments were collected by Dr. J. A. Word, Mr. J. C. Coley, and Mr. L. D. Antrim, Battelle/Marine Sciences Laboratory, Sequim, WA.

Review comments were received from Mr. Peter Haase of the California Regional Water Quality Control Board and Dr. W. H. Patrick, Jr., of the Port of Oakland. Additional technical review was provided by Drs. Judith Pennington and Douglas Gunnison, ERSD. The final report reflects revision to address the comments received.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Leonard G. Hassell, EN.

This report should be cited as follows:

Lee, C. R., Tatem, H. E., Simmers, J. W., Skogerboe, J. G., Folsom, B. L., Jr., Price, R. A., Brannon, J. M., Brandon, D. L., Price, C. L., Averett, D. E., and Palermo, M. R. 1992. "Evaluation of Upland Disposal of Oakland Harbor, California, Sediment; Vol 1: Turning Basin Sediments," Miscellaneous Paper EL-92-12, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

# CONTENTS

	<u>Page</u>
SUMMARY . . . . .	1
PREFACE . . . . .	7
LIST OF TABLES . . . . .	10
LIST OF FIGURES . . . . .	14
CONVERSION FACTORS, NON-SI TO SI UNITS OF MEASUREMENT . . . . .	16
PART I: INTRODUCTION . . . . .	17
Background . . . . .	17
Purpose and Scope . . . . .	20
PART II: SEDIMENT CHARACTERIZATION . . . . .	22
Methods and Materials . . . . .	22
Results . . . . .	33
Discussion . . . . .	33
PART III: EFFLUENT TEST . . . . .	39
Methods and Materials . . . . .	39
Results . . . . .	41
Effluent Impacts and Control . . . . .	45
PART IV: SURFACE RUNOFF TEST . . . . .	53
Background . . . . .	53
Methods and Materials . . . . .	54
Results . . . . .	58
Discussion . . . . .	64
Surface Runoff Impacts and Controls . . . . .	65
PART V: LEACHATE TEST . . . . .	71
Methods and Materials . . . . .	71
Results . . . . .	77
Discussion . . . . .	101
Leachate Impacts and Controls . . . . .	104
PART VI: PLANT TEST . . . . .	117
Methods and Materials . . . . .	117
Results and Discussion . . . . .	125
Plant Impact and Controls . . . . .	135
PART VII: ANIMAL TESTS . . . . .	138
Methods and Materials . . . . .	138
Results and Discussion . . . . .	139
Conclusions . . . . .	151
PART VIII: CONCLUSIONS AND RECOMMENDATIONS . . . . .	155
PART IX: REFERENCES . . . . .	156
APPENDIX A: SEDIMENT COLLECTION AND CHEMICAL CHARACTERIZATION . . . . .	A1
APPENDIX B: EFFLUENT TEST . . . . .	B1
APPENDIX C: SURFACE RUNOFF TEST . . . . .	C1



	<u>Page</u>
APPENDIX D: LEACHATE TEST . . . . .	D1
APPENDIX E: PLANT TEST . . . . .	E1
APPENDIX F: ANIMAL TEST . . . . .	F1

# LIST OF TABLES

<u>No.</u>		<u>Page</u>
1	Chemical Analysis of Upper and Lower Oakland Harbor Sediments and Twitchell Island and 7th Street Soils . . . . .	34
2	Replicated Chemical Analysis of Upper and Lower Oakland Harbor Sediments . . . . .	36
3	Background Levels and Allowable Applications of Several Heavy Metals for US Cropland Soils . . . . .	36
4	Analytical Results Summary--Levee Soils . . . . .	37
5	Modified Elutriate Results for Upper Composite Sample . . . . .	42
6	Modified Elutriate Results for Lower Composite Sample . . . . .	43
7	Water Quality Criteria and Standards for Comparison to Test Results . . . . .	44
8	Predicted Effluent Total Concentrations for Upper Composite . . . . .	46
9	Predicted Effluent Total Concentrations for Lower Composite . . . . .	47
10	Estimated Mass Release for Upper Composite . . . . .	48
11	Estimated Mass Release for Lower Composite . . . . .	49
12	Total Mass Release for Upper Composite . . . . .	50
13	Total Mass Release for Lower Composite . . . . .	51
14	Contaminant Concentrations in Oakland Harbor Sediment . . . . .	59
15	Surface Runoff Water Quality from Oakland Harbor Sediment . . . . .	59
16	Heavy Metal Concentrations in Surface Runoff from Oakland Harbor Sediments . . . . .	60
17	PAH Concentrations in Surface Runoff Water . . . . .	63
18	Surface Runoff Contaminants Exceeding Water Quality Criteria or Standards . . . . .	66
19	Experimental Sequence for Determining Appropriate Shaking Times for Anaerobic Kinetic Testing of Oakland Harbor Sediment . . . . .	72
20	Test Sequence for Sequential Batch Leaching of Anaerobic Oakland Harbor Sediment for Metals and Tributyltin . . . . .	75
21	Heavy Metal and Butyltin Concentrations in Anaerobic Oakland (Upper) Harbor Leachate at Different Sampling Times . . . . .	78
22	Heavy Metal and Butyltin Concentrations in Anaerobic Oakland (Lower) Harbor Leachate at Different Sampling Times . . . . .	79

<u>No.</u>		<u>Page</u>
23	Heavy Metal Leachate Concentrations in Aerobic Oakland (Upper) Harbor Sediment at Different Sampling Times . . . . .	80
24	Heavy Metal Leachate Concentrations in Aerobic Oakland (Lower) Harbor Sediment at Different Sampling Times . . . . .	81
25	Leachate pH and Conductivity in Oakland Harbor Sequential Batch Leachate Testing . . . . .	82
26	Steady-State Heavy Metal Sediment Concentrations in Anaerobic Oakland (Upper) Harbor Sediment . . . . .	84
27	Heavy Metal Concentrations in Leachate from Anaerobic Oakland (Upper) Harbor Sediment . . . . .	85
28	Steady-State Heavy Metal Sediment Concentrations in Anaerobic Oakland (Lower) Harbor Sediment . . . . .	86
29	Heavy Metal Concentrations in Leachate from Anaerobic Oakland (Lower) Harbor Sediment . . . . .	87
30	Steady-State Heavy Metal Sediment Concentrations in Aerobic Oakland (Upper) Harbor Sediment . . . . .	88
31	Heavy Metal Concentrations in Leachate from Aerobic Oakland (Upper) Harbor Sediment . . . . .	89
32	Steady-State Heavy Metal Sediment Concentrations in Aerobic Oakland (Lower) Harbor Sediment . . . . .	90
33	Heavy Metal Concentrations in Leachate from Aerobic Oakland (Lower) Harbor Sediment . . . . .	91
34	Steady-State Butyltin Sediment and Leachate Concentrations in Anaerobic Oakland (Upper) Harbor Sediment . . . . .	96
35	Steady-State Butyltin Sediment and Leachate Concentrations in Anaerobic Oakland (Lower) Harbor Sediment . . . . .	97
36	Steady-State Butyltin Sediment and Leachate Concentrations in Aerobic Oakland (Upper) Harbor Sediment . . . . .	98
37	Steady-State Butyltin Sediment and Leachate Concentrations in Aerobic Oakland (Lower) Harbor Sediment . . . . .	99
38	Interstitial Water Metal and Organotin Compound Concentrations in Anaerobic Oakland Harbor Sediment . . . . .	101
39	Cumulative Mass Loss of Metals and Organotin Compounds from Oakland Harbor Sediments Following Seven Cycles of Leaching for Metals and Five Cycles of Leaching for Organotin Compounds . . . . .	102

<u>No.</u>		<u>Page</u>
40	Percent Mass Loss of Heavy Metals from Oakland Harbor Sediment Under Anaerobic and Aerobic Conditions Following Seven Sequential Batch Leach Cycles . . . . .	102
41	Evaluation of Leachate Movement through Oakland Upper Sediment . . . . .	107
42	Evaluation of Leachate Movement through Oakland Lower Sediment . . . . .	108
43	Comparison of Percolation Volumes to Batch Leaching Test Volumes . . . . .	112
44	Comparison of Leachate Concentrations to Regulatory Limits for Oakland (Upper) Harbor Sediment . . . . .	113
45	Comparison of Leachate Concentrations to Regulatory Limits for Oakland (Lower) Harbor Sediment . . . . .	113
46	Worst-Case Flux Estimates for Leachate from Oakland (Upper) Harbor Sediment . . . . .	115
47	Worst-Case Flux Estimates for Leachate from Oakland (Lower) Harbor Sediment . . . . .	115
48	Wash Water Butyltin Concentrations from Upper and Lower Oakland Harbor . . . . .	126
49	Sediment Concentration of Butyltin from Upper and Lower Oakland Harbor after Being Air-Dried and Washed . . . . .	127
50	Wash Water pH, Electrical Conductivity, Salinity, Suspended Solids, and Heavy Metals in Sediments from Upper and Lower Oakland Harbor . . . . .	128
51	Total Sediment Concentration of Heavy Metals, pH, Electrical Conductivity, and Salinity, as Affected by Washing . . . . .	130
52	DTPA Extract Concentration of Heavy Metals in Sediments from Oakland and Soils from 7th Street and Twitchell Island as Affected by Washing . . . . .	131
53	Yield of <i>Sporobolus virginicus</i> and <i>Cyperus esculentus</i> Grown on Sediments from Oakland Harbor, 7th Street, and Twitchell Island . . . . .	132
54	Heavy Metal Tissue Content in <i>Sporobolus virginicus</i> and <i>Cyperus esculentus</i> Grown on Sediments from Oakland Harbor and on Soils from 7th Street and Twitchell Island . . . . .	133
55	Total Plant Uptake of Heavy Metals by <i>Sporobolus virginicus</i> and <i>Cyperus esculentus</i> Grown on Sediments from Oakland Harbor and on Soils from 7th Street and Twitchell Island . . . . .	134
56	Plant Butyltin Content . . . . .	136

<u>No.</u>		<u>Page</u>
57	Earthworm 72-hr Toxicity Test . . . . .	140
58	Results of Earthworm Toxicity Test of Reference Manure, 7th Street Soil, Twitchell Island Soil, and Lower and Upper Oakland Harbor Sediments . . . . .	141
59	Concentrations of Metals in Substrates and Tissues of Bioassay Earthworms . . . . .	142
60	Concentrations of Organotins in Substrates and Tissues of Bioassay Earthworms . . . . .	143
61	Concentrations of PCBs in Substrates and Earthworm Tissues . . . . .	143
62	Concentrations of Pesticides in Substrates and Earthworm Tissues . . . . .	144
63	Concentrations of Semivolatile PAHs in Substrates and Earthworm Tissues . . . . .	145
64	Summary Matrix of Information on Earthworm Accumulation of Contaminants . . . . .	147
65	Summary of Tributyltin Concentrations in Sediments and Animals, from Available Literature . . . . .	152

# LIST OF FIGURES

<u>No.</u>		<u>Page</u>
1	Oakland Harbor deepening and widening project map . . . . .	18
2	Sediment core sampling stations in turning basin area of Oakland Inner Harbor . . . . .	23
3	Soil sampling location--Twitchell Island disposal site . . . . .	24
4	Soil sampling location--7th Street disposal site . . . . .	25
5	Barrels were emptied into soil bed lysimeter for mixing . . . . .	26
6	Sediment was mixed manually with shovels, rakes, and hoes . . . . .	26
7	Lightning Mixer was used to thoroughly mix sediment . . . . .	27
8	Random samples were removed from the soil bed lysimeter and placed in barrels . . . . .	27
9	Additional samples were randomly collected from all sections of the soil bed lysimeter for individual tests . . . . .	28
10	Mixed sediments were collected in barrels and taken to a refrigerated building . . . . .	28
11	Barrels of mixed sediment were placed in a refrigerated room at 4° C until tested . . . . .	29
12	Soil beds were covered after mixing . . . . .	29
13	Oakland upper sediment was placed in an aluminum drying flat to dry and oxidize prior to plant and animal bioassay testing . . . . .	30
14	Dried and oxidized Oakland upper sediment . . . . .	30
15	Oakland lower sediment drying in aluminum drying flat . . . . .	31
16	Glass columns of sediment/water elutriate mixture . . . . .	40
17	Rainfall simulation on anaerobic oakland upper sediment . . . . .	55
18	Runoff rate measurements were taken throughout the rainfall simulation . . . . .	55
19	Soil bed of anaerobic Oakland upper sediment just after a simulated rainfall event . . . . .	56
20	Soil bed of dried and oxidized Oakland upper sediment prior to rainfall simulation . . . . .	57
21	View of agricultural fields on the interior of Twitchell Island (drainage ditch pump shown in lower right corner) . . . . .	68
22	Discharge pump that pumps surface water out of drainage ditch from the interior of Twitchell Island . . . . .	69
23	Twitchell Island drainage water is discharged through a pipe into the San Joaquin River . . . . .	69
24	Anaerobic sediments are leached under a nitrogen atmosphere in a glove box . . . . .	73

<u>No.</u>		<u>Page</u>
25	Filtering of anaerobic sediment leachates is performed in a nitrogen atmosphere . . . . .	74
26	Centrifuge tubes with anaerobic sediment are stored under a nitrogen atmosphere . . . . .	74
27	Arsenic concentrations in Oakland Harbor sequential batch leachate . . . . .	92
28	Copper concentrations in Oakland Harbor sequential batch leachate . . . . .	93
29	Zinc concentrations in Oakland Harbor sequential batch leachate . . . . .	94
30	Tributyltin concentrations in Oakland Harbor sequential batch leachate . . . . .	100
31	Falling head permeability data for Oakland Harbor (upper) . . . . .	105
32	Falling head permeability data for Oakland Harbor (lower) . . . . .	105
33	Typical cross section of levee and drainage system . . . . .	110
34	HELP model estimates of annual percolation rates for CDF alternatives . . . . .	111
35	HELP model estimates of cumulative percolation volume for CDF alternatives . . . . .	111
36	Plant bioassay apparatus . . . . .	119
37	Appearance of <i>Sporobolus virginicus</i> growing in the various test substrates . . . . .	121
38	Appearance of <i>Cyperus esculentus</i> growing in the various test substrates . . . . .	121
39	Harvesting of plants after growth in various test substrates . . . . .	122
40	Earthworm bioassay apparatus . . . . .	139

CONVERSION FACTORS, NON-SI TO SI  
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI units as follows:

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
acres	4,046.873	square meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
gallons (US liquid)	3.785412	liters
inches	2.54	centimeters
miles (US statute)	1.609347	kilometers
pounds (mass)	0.4535924	kilograms
pounds (mass) per acre	0.000112	kilograms per square meter
square feet	0.09290304	square meters
square miles	2.589998	square kilometers
tons (metric) per hectare	0.10	kilograms per square meter



EVALUATION OF UPLAND DISPOSAL OF OAKLAND  
HARBOR, CALIFORNIA, SEDIMENT

VOLUME I: TURNING BASIN SEDIMENTS

PART I: INTRODUCTION

Background

Construction of both the Oakland Outer Harbor Deepening Project and the Oakland Inner Harbor Deepening Project was authorized by the Water Resources Development Act of 1986, 99th Congress, 2nd Session, Public Law 99-662 (US Army Corps of Engineers (USACE) 1987).

The plan authorized for Oakland Outer Harbor in 1986 called for widening and deepening of the existing 3.4-mile\* Oakland Outer Harbor Channel to -42 ft mllw (Figure 1). This plan would require the dredging of approximately 4.9 million cubic yards of bottom sediments, which were proposed for disposal at the Alcatraz Site SF-11 during ebb tide cycle. Annual maintenance dredging and disposal would be required for an additional 88,000 cu yd of material.

The authorized plan for Oakland Inner Harbor called for deepening the existing navigational channels from -35 ft to -42 ft mllw between the Oakland Inner Harbor Entrance Channel and the Clay Street Pier at project mile 4.4 (Figure 1). This plan would require the dredging and disposal of 4.4 million cubic yards of material, which were proposed for disposal at Alcatraz. Annual maintenance dredging and disposal would be required for an additional 70,000 cu yd of material.

Modifications to the authorized plan were made in 1987 to reduce the amounts of material dredged to 2.8 and 3.7 million cubic yards for the Oakland Outer Harbor and the Oakland Inner Harbor, respectively (USACE 1987).

Sediments were sampled and tested to evaluate the potential for impacts during disposal operations at the proposed Alcatraz disposal site. All material was found to be suitable for unrestricted open-water disposal, except samples collected from the turning basin area of the Oakland Inner Harbor. These sediments were determined to be unsuitable for unrestricted open-water

---

\* A table of factors for converting non-SI units of measurement to SI units is presented on page 16.

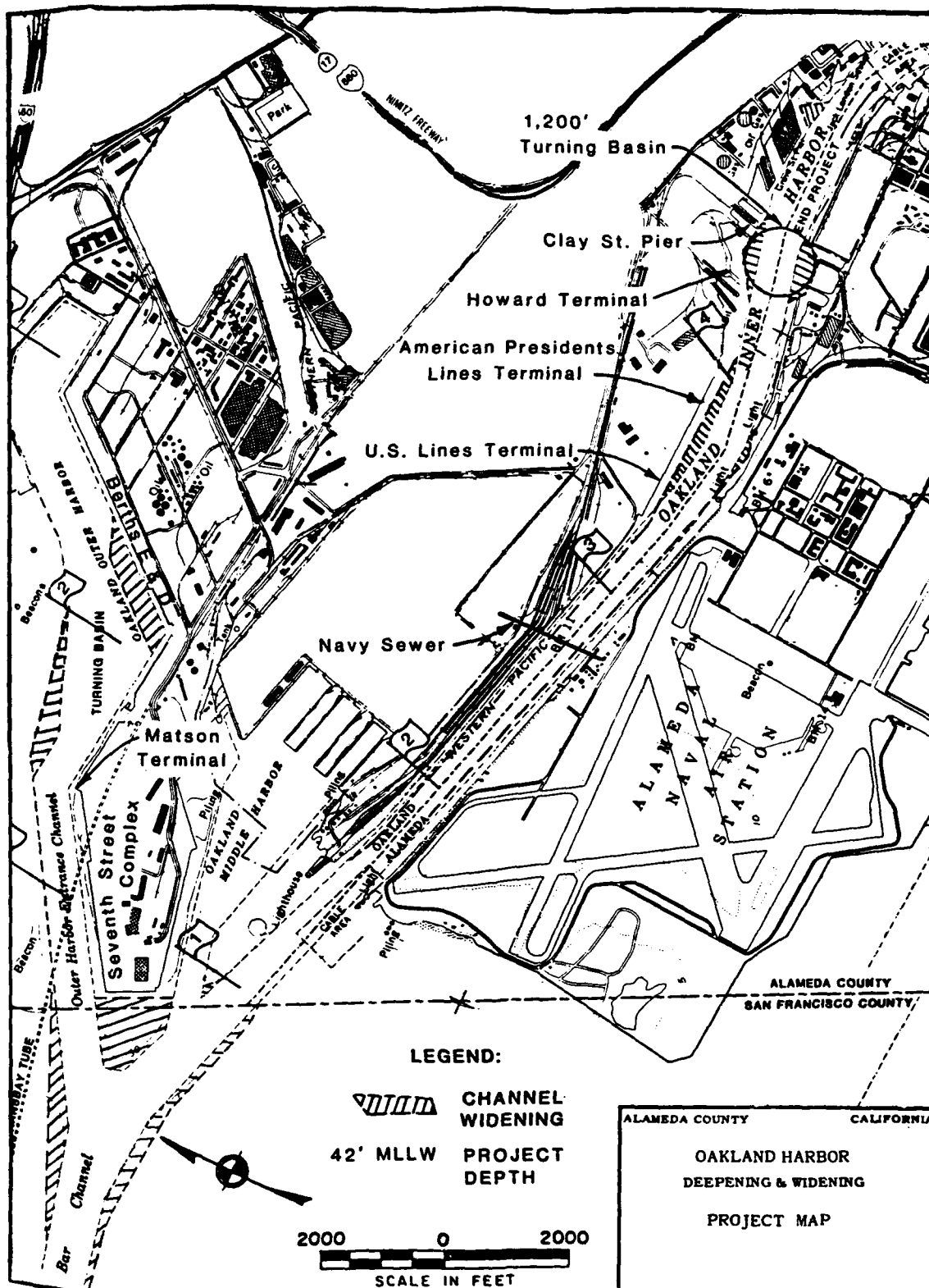


Figure 1. Oakland Harbor deepening and widening project map

disposal. Therefore, other disposal alternatives would have to be evaluated for these sediments.

The US Army Engineer Waterways Experiment Station (WES) was asked to assist in the evaluation of other alternatives, such as upland disposal, for the sediments from the turning basin area of Oakland Inner Harbor. Francingues et al. (1985) and Lee et al. (1991) described the Corps' Management Strategy for Disposal of Dredged Material, in which a sediment is tested and evaluated for potential disposal site environments, including aquatic, wetland, and upland. These test protocols are used in the present evaluation (Volume I) to determine the potential for migration of contaminants into effluent, surface runoff, leachates, plants, and animals at an upland disposal site. These same test protocols were used in a second evaluation (Volume II) to determine the potential for migration of contaminants in sediments from the rest of the dredging project, both Inner and Outer Oakland Harbors.

The Corps' management strategy has been applied in total or in part to the following dredging projects:

- Everett Homeport Project, Washington
- Black Rock Harbor, Connecticut
- Indiana Harbor, Indiana
- Blue River Project, Kansas City, MO
- New Bedford Harbor, Massachusetts
- Baltimore Harbor, Maryland
- Southwest Pass, Louisiana
- Corpus Christi Harbor, Texas
- Bridgeport Harbor, Connecticut
- Oakland Harbor, California
- Duwamish Waterway, Washington
- Michigan City Harbor, Indiana
- Detroit River, Michigan
- Menominee River, Wisconsin
- Milwaukee Harbor, Wisconsin
- Times Beach Confined Disposal Facility (CDF) Site, Buffalo, NY
- Toledo Harbor CDF, Toledo, OH
- Benton Harbor, Michigan
- Acid Mine Spoil Restoration, Ottawa, IL
- Dike 12 CDF, Cleveland, OH
- Lock and Dam 2, St. Paul, MN
- Pointe Mouillee, Michigan
- Broekpolder, Rotterdam, The Netherlands

The Corps' management strategy test protocols have also been applied to a number of other contaminated sites such as:

- Naval Weapons Station, Concord, CA
- Naval SUBASE, Bangor, WA
- PCB spill site, Delft, The Netherlands
- Metal mining waste sites, Wales, United Kingdom

Agricultural sites, Haren, The Netherlands  
Wetland sites, Eastern Scheldt, The Netherlands  
Sewage sludge amended soils, Beltsville, MD  
Roadside contamination sites, Chicago, IL  
Agricultural sites, Montpellier, France  
Wetland sites, Lisbon, Portugal

Test results have been used to evaluate potential contaminant migration and to formulate management strategies and/or remedial actions at these sites.

#### Purpose and Scope

The purpose of this report is to describe the results of a comprehensive evaluation of the impact of placing the Oakland Harbor sediment in an upland disposal environment. The evaluation considered the reuse of the sediment as material for rebuilding levees along the lower Sacramento and San Joaquin Rivers. Contaminant migration via effluent, surface runoff, leachate, and plant and animal uptake was evaluated. Contaminants of concern were salt, metals, tributyltin (TBT), polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).

Test results were interpreted in relation to existing Federal criteria and/or State standards, or existing related data and information from literature and past or present research projects. Normally, test results of water quality data from filtered water samples were evaluated in relationship to Federal water quality criteria and/or State water quality standards for effluents and receiving waters. Water quality objectives are being developed by the State of California and can be used for comparison in the future. In response to comments received on the draft report of this study by the California Regional Water Quality Control Board (CRWQCB), water quality data from unfiltered water samples were evaluated in relationship to existing Federal and State water quality criteria and standards. This approach is not recommended, but will be discussed in response to comments received on the draft report. Evaluating unfiltered water quality data in relationship to water quality criteria or standards is overly protective of the aquatic environment and will usually result in concluding the need for restrictions and controls for discharged effluents and surface runoff water unnecessarily. This may translate to increased project cost without any additional environmental protection. Therefore, it is recommended that the evaluation of test

results should be made on filtered water data and not on unfiltered water data.

Interpretation of water quality test data considered the means of replicates and the variance of data around the mean to predict potential impacts. The mean, in this instance, is a better indicator of predicted water quality than the individual values. These laboratory tests give predictions of water quality for specific conditions and should be considered an indication of the potential of an effluent, surface runoff, or leachate to meet or exceed criteria or standards. In response to comments received from CRWQCB to compare maximum water quality values observed in the test replicates to water quality criteria or standards, it is recommended that these comparisons not be made. Such comparisons are required by regulation for field testing and monitoring of discharges; however, they are inappropriate for the laboratory test results of this project.

Test data will be discussed in terms of statistical differences. Statistical means differences were measured at the  $P = 0.05$  level of significance using standard statistical procedures that consider variability in test data to separate data means. The use of the words significant and/or substantial increase or amount describes the magnitude of an increase or amount and will be interpreted in this report to mean that the increase or amount is important ecologically.

## PART II: SEDIMENT CHARACTERIZATION

### Methods and Materials

#### Sediment collection, transport, and mixing

Sediment was collected from the turning basin in Oakland Inner Harbor (Figures 1 and 2) using a vibracoring sampler (see Appendix A for further details). Twenty-one sediment samples from core depths to 38 ft were composited into 55-gal barrels and labeled "upper sediment." Sediment from core depths between 38 and 45 ft was composited into other 55-gal barrels and labeled "lower sediment." In addition, soil was collected from two reference sites, which are potential disposal sites for the dredged sediment. One reference site is Twitchell Island levee (Figure 3), and the other is a site at 7th Street in Oakland (Figure 4) (see Appendix A for further details). Sediment placed on the Twitchell Island levee would be used to rebuild the levee. Sediment placed on the 7th Street site would be contained, reconditioned, and eventually removed from the site.

All barrels of collected sediments and soils were loaded into a refrigerated trunk and transported to the WES. The barrels were placed in a cold storage room (4 °C) for 5 days prior to mixing.

Barrels of lower sediment were removed from the cold storage room and poured into a lined 4- by 15- by 4-ft soil bed lysimeter (Figure 5). The sediment was mixed by hand with shovels and mechanically with a Lightning Mixer (Figures 6 and 7). After mixing, subsamples were randomly collected from the entire soil bed for use in the different test protocols (Figures 8 and 9). Mixed sediment samples were containerized and stored in a cold storage facility (4 °C) until used (Figures 10 and 11). Barrels of the upper sediment were poured into another soil bed lysimeter, mixed, and subsampled in a similar manner. Soil beds were covered for protection prior to initiation of surface runoff tests (Figure 12). Sediments were air-dried in aluminum drying flats prior to upland tests (Figures 13-15). The soil from each reference site was air-dried and passed through a 2.54-cm screen to remove stones. These sediments and soils were used to conduct the tests for upland disposal evaluations.

#### Sediment and soil characterization

Sediment and soil samples were shipped by overnight delivery to Dr. Eric Greclius at Battelle Pacific Northwest Laboratories, Sequim, WA, and were

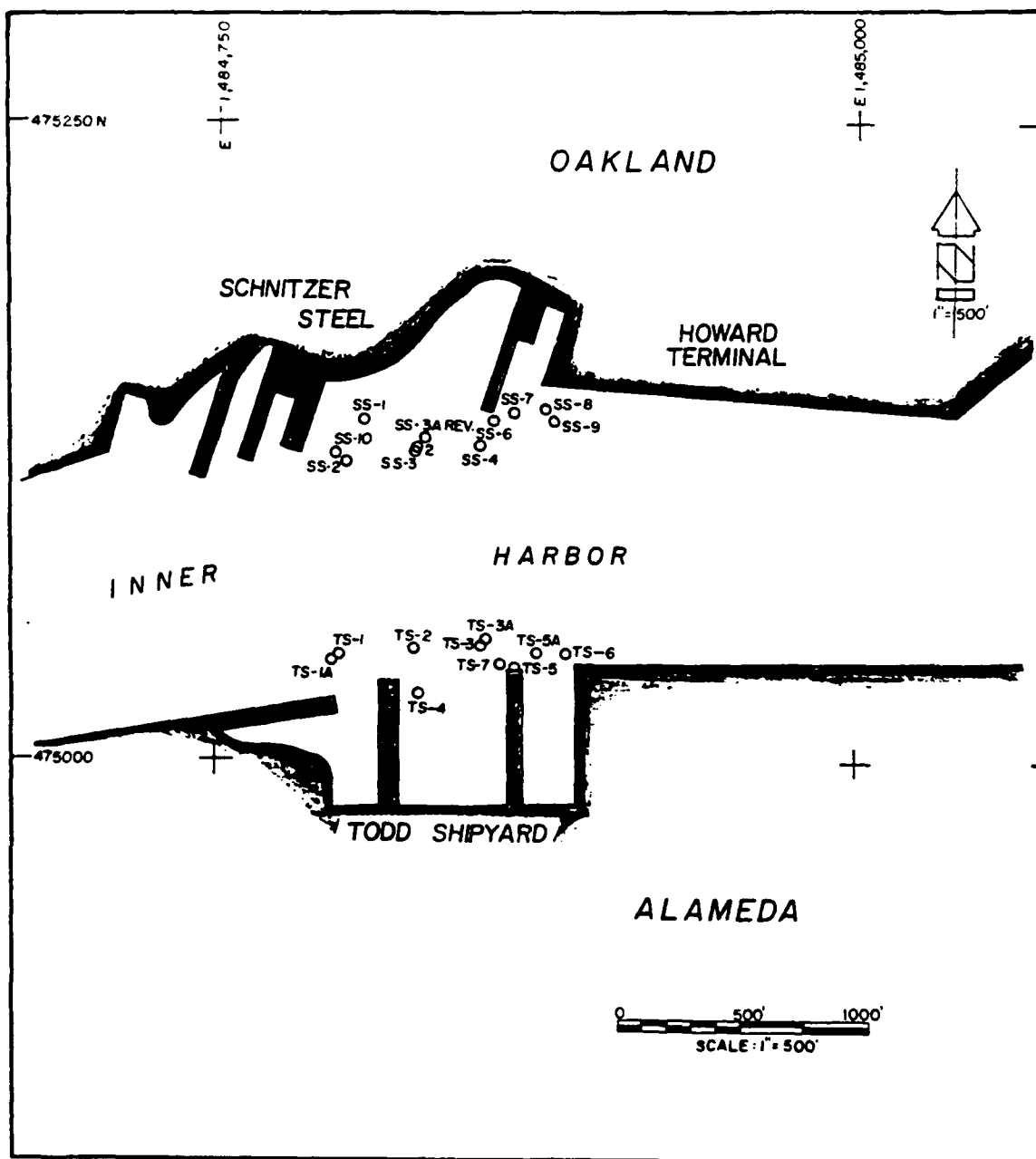


Figure 2. Sediment core sampling stations in turning basin area of Oakland Inner Harbor

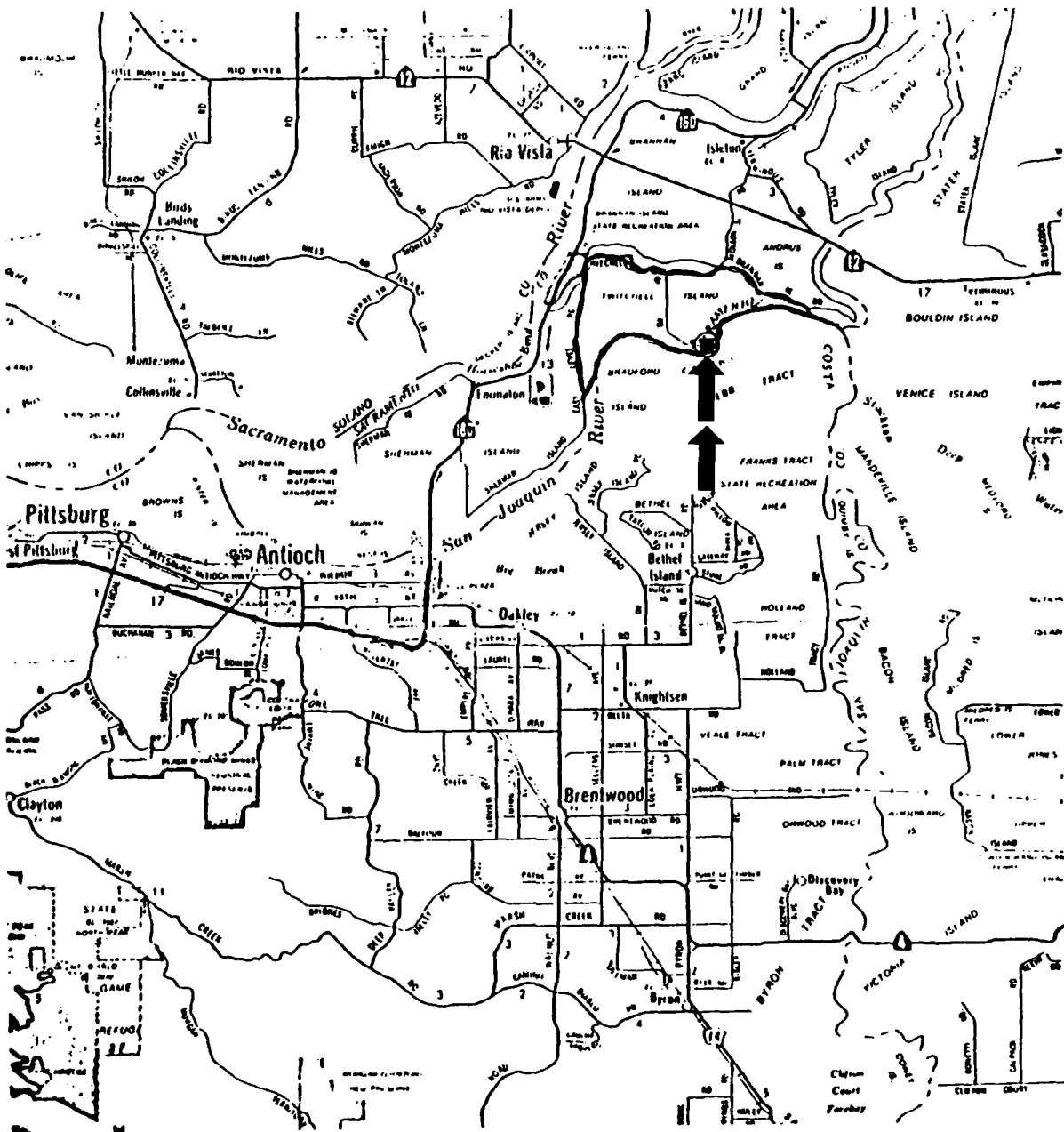


Figure 3. Soil sampling location--Twitchell Island disposal site







Figure 5. Barrels were emptied into soil bed lysimeter for mixing



Figure 6. Sediment was mixed manually with shovels, rakes, and hoes



Figure 7. Lightning Mixer was used to thoroughly mix sediment



Figure 8. Random samples were removed from the soil bed lysimeter and placed in barrels



Figure 9. Additional samples were randomly collected from all sections of the soil bed lysimeter for individual tests



Figure 10. Mixed sediments were collected in barrels and taken to a refrigerated building



Figure 11. Barrels of mixed sediment were placed in a refrigerated room at 4 °C until tested



Figure 12. Soil beds were covered after mixing



Figure 13. Oakland upper sediment was placed in aluminum drying flat to dry and oxidize prior to plant and animal bioassay testing



Figure 14. Dried and oxidized Oakland upper sediment



Figure 15. Oakland lower sediment drying in aluminum drying flat

were analyzed for the metals silver (Ag), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), nickel (Ni), lead (Pb), tin (Sb), and zinc (Zn) and for butyltins, pesticides, PCBs, volatile organics, and semi-volatiles/PAHs. Freeze-dried and ground sediment samples were analyzed by energy-dispersive X-ray fluorescence for As, Cr, Cu, Ni, Pb, and Zn (Nielson and Sanders 1983). The other metals were analyzed by atomic absorption spectrometry (AAS) after the sediment was totally dissolved in a mixture of nitric, perchloric, and hydrofluoric acids at an elevated temperature (130 °C) in a sealed Teflon container. Mercury was quantified by cold vapor atomic absorption spectrometry (AA) and the other metals (Ag, Cd, and Sb) were quantified by Zeeman graphite furnace AA with matrix modifiers. Sediment and tissue samples were extracted with a mixture of methylene chloride, tropolone, and sodium sulfate for the TBT analyses. The extract was derivatized and analyzed by gas chromatography with a flame photometric detector (GC-FPD), similar to the method of Unger et al. (1986). Sediments were analyzed for base-neutral acids using the US Environmental Protection Agency (USEPA) Method 625, which indicates solvent extraction, column cleanup, and the quantification by GC/mass spectrometry (MS). The PCBs and DDT were analyzed by USEPA

Method 8080, which quantified by GC-electron capture detector (ECD).

Volatiles were analyzed by USEPA Method 624 using GC/MS.

All samples for tributyltin analyses were placed in hexane-rinsed and oven-dried amber glass containers and frozen prior to shipping. Water samples for metals analyses were placed in acid-rinsed glassware and acidified with Baker Insta-Analyze concentrated nitric acid (1 ml/1 l of sample).

Organic matter (OM) was determined by weight loss on ignition at 550 °C on upland sediment. Procedure No. 209E (American Public Health Association 1976) was used for this test. A 5-g subsample (oven-dry weight) of the sediment was weighed to the nearest 0.001 g and dried at  $105 \pm 2$  °C until constant weight. Five grams (weighed to the nearest 0.001 g) of the oven-dried sediment were then combusted at  $550 \pm 5$  °C for 24 hr in a muffle furnace. The sample was allowed to cool to room temperature and weighed to the nearest 0.001 g. Weight loss on ignition was calculated and reported as percent organic matter (%OM). The following formula was used to calculate the percent organic matter:

$$\%OM = \frac{\text{Weight oven-dried sediment} - \text{Weight combusted sediment}}{\text{Weight oven-dried sediment}} * 100$$

#### Water and extracts

Water samples and DTPA extracts and acid digestates of sediments were analyzed for metals by graphite furnace AA, except for mercury, which was analyzed by cold vapor AA. Samples of water were analyzed for PAHs by USEPA Method 610 (GC-flame ionization detector (FID)). Water samples were extracted with a mixture of hexane-tropolone for the TBT analyses, derivatized with n-hexyl magnesium bromide, and quantified by GC-FPD similar to the method of Unger et al. (1986).

#### Tissues

Tissue samples were freeze-dried and digested with nitric and perchloric acid at 130 °C in a sealed Teflon container. The digestates were analyzed for Hg by cold vapor AA, and the other metals were quantified by Zeeman graphite furnace AA. Worm tissue was analyzed for PAHs by USEPA Method 8100 (GC-FID) and PCBs by USEPA Method 8080 (GC-ECD). Sediment and tissue samples for TBT analyses were extracted with a mixture of methylene chloride, tropolone, and



sodium sulfate. The extract was derivatized and analyzed by GC-FPD similar to the method of Unger et al. (1986).

### Results

Results of chemical analyses of the upper and lower sediments from Oakland Harbor and the reference soils from Twitchell Island and the 7th Street disposal site are presented in Tables 1 and 2. These data showed that upper and lower Oakland Harbor sediments contained butyltin compounds, but that concentrations were less than 1.0 mg/kg or ppm. The upper layer was 20 times more contaminated with butyltins than the lower layer. Twitchell and 7th Street sediments did not contain butyltins. All four sediments and soils contained detectible concentrations of metals; 7th Street was relatively high in As, Cu, Pb, Sb, and Zn. These sediments and soils contained only low concentrations of PCBs. Pesticides, except for DDE and DDT, were less than detection limits. Twitchell Island soil contained the highest concentration of volatiles-methylene chloride. Upper Oakland sediment contained the highest concentrations of PAHs. Sediment organic matter was higher in the upper Oakland sediment (5.14 percent) compared to the lower Oakland sediment (2.12 percent).

### Discussion

The discussion of sediment characterization will be divided and focused on each of the two potential disposal sites: Twitchell Island, where a beneficial use of the dredged material will be for rebuilding levees, and the 7th Street site, where dredged material will be contained, reconditioned, and eventually removed from the site.

#### Twitchell Island

The concentrations of Pb, Zn, Cu, and Cd in both the upper and lower Oakland sediments were below the allowable concentration for sewage sludge-amended soils according to the US Department of Agriculture (USDA) (Table 3). Nickel concentrations in the upper sediment were slightly above the 82-mg/kg limit shown in Table 3. With this exception, the sediment from Oakland would be suitable for agricultural crop production in relation to these metals. The metal contents of the lower Oakland sediment were in the range of those values reported for Twitchell Island levee soil (Table 4) by Harding Lawson

Table 1  
Chemical Analysis of Upper and Lower Oakland Harbor Sediments  
and Twitchell Island and 7th Street Soils\*

Parameter	Concentration, mg/kg (dry weight)			
	Upper Oakland	Lower Oakland	Twitchell Island	7th Street
Butyltins				
Tri	0.754	0.024	<0.002	<0.002
Di	0.108	0.008	<0.002	0.002
Mono	0.012	0.002	<0.002	0.002
Total	0.874	0.034	--	--
Metals				
Ag	0.75	0.25	0.14	0.62
As	8.9	5.4	14.7	24.5
Cd	0.87	0.26	0.46	0.58
Cr	336.0	571.0	129.0	348.0
Cu	91.0	35.0	41.0	583.0
Hg	1.04	0.46	0.21	0.3
Ni	116.0	66.0	73.0	65.0
Pb	80.0	20.0	13.0	120.0
Sb	1.94	0.56	1.20	5.83
Zn	225.0	74.0	96.0	303.0
Pesticides/PCBs				
Aroclor 1254	0.12	0.06	<0.02	0.04
Alpha-BHC to dieldrin	<0.002	<0.002	<0.002	<0.002
4,4'-DDE	<0.004	<0.002	0.003	<0.002
Endrin to endosulfan sulfate	<0.005	<0.003	<0.003	<0.003
4,4'-DDT	<0.005	<0.002	0.006	0.010
Methoxychlor	<0.006	<0.004	<0.004	<0.004
Endrin ketone	<0.003	<0.002	<0.002	<0.004
Gamma-chlordane	<0.003	<0.002	<0.001	0.002
Alpha-chlordane	<0.002	<0.001	<0.001	0.001
Toxaphene	<0.225	<0.150	<0.150	<0.150
Volatiles				
Methylene chloride	0.12	0.03	1.60	0.18
Acetone	0.07	0.03	0.02	<0.006
Ethylbenzene	0.004	0.006	<0.001	<0.001
Total xylenes	0.02	0.04	<0.002	<0.002

(Continued)

\* Data presented in this table are for one sample only, no replicates. See example data sheets (Appendix A) for listing of all pesticides or volatile and semivolatile organic contaminants for which analyses were conducted.

Table 1 (Concluded)

<u>Parameter</u>	<u>Concentration, mg/kg (dry weight)</u>			
	<u>Upper</u> <u>Oakland</u>	<u>Lower</u> <u>Oakland</u>	<u>Twitchell</u> <u>Island</u>	<u>7th</u> <u>Street</u>
Semivolatiles				
Naphthalene	0.14	0.06	<0.02	0.02
2-methyl naphthalene	0.02	0.01	<0.02	0.01
Acenaphthylene	0.07	0.02	<0.02	<0.02
Acenaphthene	0.61	0.21	<0.02	0.02
Fluorene	0.15	0.10	<0.02	0.01
Phenanthrene	2.60	1.10	0.05	0.12
Anthracene	0.85	0.30	<0.02	0.03
Fluoranthene	3.40	1.20	0.26	0.18
Pyrene	3.60	1.20	0.32	0.15
Benzo(a)anthracene	1.10	0.33	0.07	0.06
Chrysene	1.60	0.46	0.12	0.13
Benzo(b&k)fluoranthene	3.00	0.75	0.25	0.30
Benzo(a)pyrene	2.20	0.56	0.18	0.10
Indeno(1,2,3-cd)pyrene	1.30	0.35	0.18	0.09
Dibenz(a,h)anthracene	0.21	0.06	0.02	0.03
Benzo(g,h,i)perylene	1.40	0.35	0.21	0.07
Total PAHs	22.25	7.06	1.78	1.34
Dibenzofuran	0.03	0.01	<0.02	0.01
bis(2-ethylhexyl)phthalate	0.41	0.06	<0.02	0.02

Table 2  
Replicated Chemical Analysis of Upper and Lower  
Oakland Harbor Sediments\*

<u>Parameter</u>	<u>Concentration, mg/kg (dry weight)</u>	
	<u>Upper</u>	<u>Lower</u>
<b>Butyltins</b>		
Tri	0.702 ± 0.56	0.035 ± 0.04
Di	0.153 ± 0.13	0.007 ± 0.005
Mono	0.019 ± 0.01	0.002 ± 0.001
Total	0.874	0.044
<b>Metals</b>		
As	10.15 ± 2.0	5.40 ± 0.9
Cd	0.96 ± 0.2	0.37 ± 0.2
Cr	321.25 ± 10.8	585.75 ± 58.5
Cu	102.50 ± 12.9	40.75 ± 13.1
Hg	1.01 ± 0.1	0.54 ± 0.2
Ni	116.50 ± 4.5	67.75 ± 2.1
Pb	83.75 ± 14.4	22.75 ± 9.6
Zn	218.25 ± 12.4	78.50 ± 12.2

\* Values are means ± one standard deviation for four replicate samples.

Table 3  
Background Levels and Allowable Applications of Several  
Heavy Metals for US Cropland Soils\*

<u>Parameter</u>	<u>Background Concentration in</u> <u>Surface Soils, mg/kg</u>			<u>No Effect</u> <u>Allowed</u> <u>Addition</u> <u>kg/ha</u>	<u>Median**</u> <u>Allowed</u> <u>Application</u> <u>mg/kg</u>
	<u>5 percentile</u>	<u>Median</u>	<u>95 percentile</u>		
Lead	4.0	11	27	1,000	511
Zinc	7.3	54	129	500	304
Copper	3.7	19	96	250	144
Nickel	3.8	19	59	125	82
Cadmium	0.035	0.20	0.78	5	2.7
pH	4.6	6.1	8.1	--	--

\* Lee et al. (1991).

\*\* Allowed application is mixed into the 0 to 15 cm (0 to 6 in.) surface layer of soil.

Table 4

Analytical Results Summary--Levee Soils\*

<u>Analyte</u>	<u>Concentration Range (Average)**</u>
<u>Title 22 Metals†</u>	
Arsenic	2.0-19.6 (9.3)
Barium	37.2-211 (114.1)
Cadmium	0.93-6.4 (3.4)
Chromium	11.5-84.3 (43.8)
Cobalt	5.1-22.5 (12.1)
Copper	8.3-52.5 (29.0)
Lead	3.1-22.5 (10.8)
Mercury	0.018-1.7 (0.214)
Molybdenum	0.28-1.7 (0.98)
Nickel	14-103 (39.9)
Selenium	0.02-0.18 (0.07)
Vanadium	19.1-81.6 (53.1)
Zinc	8.46-98.8 (59.3)
<u>Other metals</u>	
Aluminum	6,450-29,800 (17,223)
Iron	8,070-47,600 (23,451)
Manganese	154-1,020 (441)
<u>Organochlorine pesticides/PCBs</u>	
4,4-DDE	1.1 µg/kg-6.4 µg/kg (3.8)
4,4-DDT	4.5 µg/kg-10.1 µg/kg (7.3)
<u>Petroleum hydrocarbons</u>	
Extractable type: Diesel	52-55 (54)
<u>Cyanides</u>	0.21-0.37 (0.29)
<u>Sulfides</u>	0.039
<u>Total organic carbon</u>	18,500-36,300 (27,400)
<u>Oil and grease</u>	36-47 (42)
<u>pH</u>	3.5-7.3 units
<u>Moisture content</u>	0.5-12.4 percent

Source: Harding Lawson Associates, 1989, "Final Water Quality Impact Evaluation, Land Disposal of Dredged Sediments from the Oakland Inner Harbor, Alameda County, California," prepared for Port of Oakland, Oakland, CA.

\* Results expressed in milligrams per kilogram, unless otherwise noted.

\*\* Range of detectable concentration only. Value given in parentheses is an average value for detectable concentrations.

† California Code of Regulations.

Associates.\* While the upper Oakland sediment showed contents of Cd and As that were in the range of the levee soil, contents of Zn, Ni, Pb, and Cu were higher than the levee soils.

It is of interest that the Cd content of the levee soils reported by Harding Lawson Associates (average of 3.4 mg/kg, maximum of 6.4 mg/kg) exceeds the maximum allowable amount for sewage sludge-amended soils (Table 3). Consequently, the levee soils would not be suitable for agricultural production because of the elevated Cd contents. Twitchell Island is used predominantly for agricultural production. Therefore, covering existing levee soils with Oakland sediment containing less than 1 mg/kg Cd would be a benefit to agriculture on the Island.

Butyltin contents of the Oakland sediments are higher than the levee soil. Personal communications with scientists knowledgeable in the field of soil fertility (Dr. Rufus Chaney, USDA-Agricultural Research Service, Beltsville, MD, and Dr. W. H. Patrick, Jr., Louisiana State University, Baton Rouge, LA) indicated that butyltins are not of concern. However, no data to substantiate this consensus were found.

Oakland sediments contained higher concentrations of PCBs and PAHs than Twitchell Island levee soils (Table 1). These higher bulk sediment chemical results indicated a need for further testing of contaminant migration pathways such as effluent, surface runoff, leachate, and plant and animal uptake at the proposed Twitchell Island disposal site.

#### 7th Street disposal site

Oakland sediments contained higher concentrations of butyltins, Hg, Ni, PCBs (Aroclor 1254), and PAHs than the 7th Street disposal site soil (Table 1). The soil from the 7th Street disposal site contained higher concentrations of As, Cu, Pb, Sb, and Zn than the Oakland sediments. These bulk chemical analysis results indicate the need for further testing of effluent, surface runoff, and leachate contaminant migration pathways at the 7th Street disposal site.

---

\* "Final Water Quality Impact Evaluation, Land Disposal of Dredged Sediments from the Oakland Inner Harbor, Alameda County, California," 1989, HLA Job No. 18721,035.02, prepared for Port of Oakland, Oakland, CA.

### PART III: EFFLUENT TEST

#### Methods and Materials

##### Applicability of test procedure

The prediction of effluent water quality from upland disposal sites is one of the evaluations described by Francingues et al. (1985) for the management of dredged material. The interpretation of the test data was generally described in the decision-making framework of Peddicord et al. (1986)\* and Lee et al. (1991). The term effluent is normally used to describe the water discharged from a confined (diked) area during hydraulic placement of dredged material. Under these conditions a pond of water is maintained within the diked area, and the volumetric flow rate of effluent is approximately equal to the volumetric inflow rate.

For the disposal operation as described for the Oakland project, the conditions for "effluent" discharge are much different. First, the material will be mechanically dredged, transported to the disposal site by barge, removed directly from the barge with a clamshell, and placed on the face of levees. These operations will result in minimal entrainment of excess water as compared to a hydraulic placement operation. Second, the disposal area is not confined by dikes in the traditional sense. Berms will collect water flowing from the material during placement but will provide only minimal retention time.

There is no standardized testing procedure for prediction of the quality of water discharged during unconfined placement of dredged material on land by mechanical equipment as described above. However, modified elutriate procedures have been developed for prediction of the quality of effluent discharged from confined disposal areas during hydraulic placement (Palermo 1985). These tests are designed to estimate both dissolved and particle-associated contaminant concentrations in the effluent. The modified elutriate test is considered a conservative ("worst-case") estimate of contaminant release for material placed by mechanical means; therefore, these procedures were used to

---

\* "General Decisionmaking Framework for Management of Dredged Material; Example Application to Commencement Bay, Washington," Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

estimate the quality of effluent discharged from the unconfined mechanical placement.

The use of modified elutriate procedures for this case is considered conservative for several reasons. The test procedures simulate the complete mixing of sediment and water during hydraulic dredging processes and would result in more potential contaminant release to water than would occur with mechanical dredging and placement. Also, the procedure calls for extraction of a sample for analysis after a settling period of 24 hr. Such a procedure would result in a higher concentration of particle-associated contaminants than would be expected for water release from a mechanically placed material because only the finer particle fractions remain after a 24-hr settling period, while for mechanical effluent, some or all particle fractions would be "washed" from the sediment mass during water loss.

#### Procedures

Modified elutriate tests were conducted (Figure 16) on composite samples of both upper and lower sediments using procedures described in Palermo (1985). All elutriate tests were conducted in triplicate using the composite sediment samples and dredging site water samples. The elutriate test procedures were conducted by the WES Analytical Laboratory Group (ALG). Analysis of physicochemical parameters in the elutriate (total suspended



Figure 16. Glass columns of sediment/water elutriate mixture



solids (TSS), pH, dissolved oxygen (DO), conductivity, and salinity) and of nutrients was performed by the ALG. Subsamples of the elutriate were preserved and transported to Battelle for analysis of metals and tri-, di-, and mono-butyltins. All analytical results are presented in Appendix B.

### Results

The replicate mean results of the modified elutriate tests are summarized in Tables 5 and 6 for the upper and lower composites, respectively. Both the mean dissolved and total concentrations of the modified elutriate are shown. For those replicates in which the elutriate results were below detection, the detection limit was used in calculating mean values.

#### Water quality standards

The estimated dissolved concentrations in the effluent are equal to the dissolved modified elutriate test concentrations as shown in Tables 5 and 6. One-tailed t-tests were used to compare the predicted dissolved effluent concentrations to the EPA Fresh and Marine Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987) and to the Effluent and Receiving Water Limitation Standards for dredging of Oakland Harbor issued by CRWQB in response to a permit application by the Port of Oakland (Table 7).

Contaminant concentrations less than or equal to the criteria were postulated as the null hypothesis. Contaminant concentrations greater than the criteria served as the alternate hypothesis. A rejection of the null hypothesis suggested values were greater than the criteria. The statistical tests were conducted using analysis of variance procedure (ANOVA), (SAS Institute, Inc. 1988). Effluent concentrations that were statistically significantly different were determined using the SAS Waller-Duncan Mean Separation Technique. All statistical tests were conducted at the  $P = 0.05$  level of significance. A detailed description of these tests is given by Winer (1971) and Sokal and Rohlf (1981).

For both the upper and lower sediments, arsenic exceeded the Receiving Water Limitation criteria. This was the only effluent parameter that exceeded any of the criteria. A dilution of less than 7 to 1 (upper sediment) or 2 to 1 (lower sediment) would be required in the mixing zone for As to meet the Receiving Water Limitation Standards, assuming zero concentration of As in the receiving water.

Table 5  
Modified Elutriate Results for Upper Composite Sample

<u>Parameter</u>	<u>Elutriate Concentrations Standard</u>		
	<u>Dissolved</u> <u>mg/l</u>	<u>Total</u> <u>mg/l</u>	<u>mg/l</u>
Arsenic	0.006347	0.008213	0.05
Cadmium	0.000097	0.000058	0.0018
Chromium	0.004003	0.003843	0.016
Copper	0.000893	0.00343	0.0092
Mercury	0.000004	0.000013	0.0024
Lead	0.015967	0.0194	0.034
Zinc	0.008333	0.014167	0.065
Tributyltin	0.000013	0.00003579	0.00008
Dibutyltin	0.000008	0.00005619	na*
Monobutyltin	0.000002	0.00000296	na
Total phosphorus	0.31	0.39	na
Orthophosphate	0.208	0.29	na
Nitrate nitrogen	0.165	0.144	na
Ammonia nitrogen	13.333	13.9	0.04
Total organic carbon	1.9	2.167	na
Conductivity, mmhos/cm	24,667	--	na
pH	8.11	--	na
DO	8.49	--	na
Salinity, ppt	15.9	--	na

\* Not available.

Table 6  
Modified Elutriate Results for Lower Composite Sample

Parameter	Elutriate Concentration Standard		
	Dissolved mg/l	Total mg/l	mg/l
Arsenic	0.00159	0.001703	0.05
Cadmium	0.000102	0.000131	0.0018
Chromium	0.003373	0.004143	0.016
Copper	0.000557	0.00124	0.0092
Mercury	0.000002	0.000002	0.0024
Lead	0.018667	0.0203	0.034
Zinc	0.011667	0.01	0.065
Tributyltin	0.000006	0.00001545	0.00008
Dibutyltin	0.000054	0.00000588	na*
Monobutyltin	0.000002	0.00000395	na
Total phosphorus	0.138	0.155	na
Orthophosphate	0.055	0.064	na
Nitrate nitrogen	0.374	0.278	na
Ammonia nitrogen	8.597	8.86	0.04
Total organic carbon	1.067	1	na
Conductivity, mmhos/cm	26,000	--	na
pH	8.07	--	na
DO	8.5	--	na
Salinity, ppt	15.9	--	na

\* Not available.

Table 7

Water Quality Criteria and Standards for Comparison to Test Results

<u>Parameter</u>	<u>USEPA Marine Acute Criterion</u>	<u>USEPA Fresh Acute Criterion</u>	<u>Effluent Limitation*</u>	<u>Receiving Water Limitation*</u>
Arsenic	69	360	50	1
Cadmium	43	3.9	1.8	0.65
Chromium	1,100	16	16	11
Copper	2.9	18	9.2	6.5
Mercury	2.1	2.4	2.4	0.012
Lead	140	82	34	--
Zinc	95	120	65	59
Tributyltin	--	--	0.080	0.020
Dibutyltin	--	--	--	--
Monobutyltin	--	--	--	--
Total butyltin	--	--	--	--

\* Limitations issued by California Regional Water Quality Control Board in response to a permit application by the Port of Oakland.

### Mass release

No standards for mass loading were specified by the CRWQCB. Therefore, predictions of the total concentration of contaminants in the effluent for an assumed range of effluent TSS from 50 to 200 mg/l were used to estimate potential mass releases. Total and dissolved concentrations were used to calculate fractions of the contaminants associated with the suspended particles as described in Palermo (1985). These results are shown in Tables 8 and 9. The total modified elutriate concentrations were equal to or lower than concentrations for the dissolved samples for some test replicates. In this case, the TSS fraction did not contribute to the total concentrations. These estimates of total concentrations were used to compute a mass release of contaminants expressed as a percentage for assumed operational conditions for mechanical placement.

The sediment contaminant concentrations for the upper and lower composite samples were used as the initial contaminant concentrations as placed (shown in Tables 10 and 11). Mechanical placement was assumed to result in minimal entrainment of water; therefore, a conservative water content for the placed material was used. A further assumption was that all of the interstitial water would be discharged as effluent (an extremely conservative assumption). The total effluent concentrations of contaminants for the assumed range of 50 to 200 mg/l of effluent TSS were then used to compute the percentage of total contaminants that would be discharged as effluent. The resulting mass releases expressed as percentages of the total contaminants placed are summarized in Tables 12 and 13.

The mass releases were generally well below 1 percent. The butyltin releases for the lower composite ranged from less than 1 percent to a high of 5.69 percent. These higher values of release expressed as a percentage reflect the fact that the initial concentrations of butyltins in the sediments for the lower composite were comparatively low. These data would indicate that the placement operation should be managed to reduce the level of suspended solids in the effluent to the greatest degree practical.

### Effluent Impacts and Control

The evaluation of effluent test results indicated that, with the exception of arsenic, the dissolved concentrations of all contaminants

Table 8

Predicted Effluent Total Concentrations for Upper Composite

<u>Parameter</u>	<u>Predicted Total Effluent Concentrations, mg/l, for Effluent TSS Concentration</u>			
	<u>50 mg/l</u>	<u>100 mg/l</u>	<u>150 mg/l</u>	<u>200 mg/l</u>
Arsenic	0.009206	0.012066	0.014926	0.017786
Cadmium	0.000097	0.000098	0.000098	0.000099
Chromium	0.004572	0.005141	0.005709	0.006278
Copper	0.004711	0.008529	0.012347	0.016165
Mercury	0.000016	0.000027	0.000039	0.000051
Lead	0.020092	0.024216	0.028341	0.032466
Zinc	0.015695	0.023058	0.030420	0.037782
Tributyltin	0.000046	0.000079	0.00011	0.000144
Dibutyltin	0.000099	0.000189	0.000279	0.000370
Monobutyltin	0.000004	0.000005	0.000006	0.000007
Total phosphorus	0.451056	0.59178	0.732503	0.873226
Orthophosphate	0.360253	0.512839	0.665425	0.818011
Nitrate nitrogen	0.164667	0.164667	0.164667	0.164667
Ammonia nitrogen	14.54567	15.75802	16.970367	18.18271
Total organic carbon	2.273851	2.647703	3.021554	3.395405
Conductivity, mmhos/cm				
pH				
DO				
Salinity, ppt	15.9	15.9	15.9	15.9

Table 9

Predicted Effluent Total Concentrations for Lower Composite

<u>Parameter</u>	<u>Predicted Total Effluent Concentrations, mg/l, for Effluent TSS Concentration</u>			
	<u>50 mg/l</u>	<u>100 mg/l</u>	<u>150 mg/l</u>	<u>200 mg/l</u>
Arsenic	0.003352	0.005114	0.006876	0.008638
Cadmium	0.000907	0.001711	0.002515	0.003319
Chromium	0.010695	0.018016	0.025338	0.032659
Copper	0.008063	0.015569	0.023075	0.03058
Mercury	0.000002	0.000002	0.000002	0.000002
Lead	0.034143	0.049619	0.065095	0.080571
Zinc	0.011667	0.011667	0.011667	0.011667
Tributyltin	0.000105	0.000204	0.000303	0.000402
Dibutyltin	0.000055	0.000055	0.000055	0.000055
Monobutyltin	0.000015	0.000028	0.00004	0.000052
Total phosphorus	0.376429	0.614524	0.852619	1.090714
Orthophosphate	0.157048	0.259429	0.36181	0.46419
Nitrate nitrogen	0.374	0.374	0.374	0.374
Ammonia nitrogen	11.62047	14.64428	17.668095	20.69190
Total organic carbon	1.066667			
Conductivity, mmhos/cm				
pH				
DO				
Salinity, ppt	15.9	15.9	15.9	15.9

Table 10  
Estimated Mass Release for Upper Composite

Parameter	Sediment Concentration mg/kg	Predicted Percentage Mass Loss for Effluent TSS Concentration			
		50 mg/l	100 mg/l	150 mg/l	200 mg/l
Arsenic	10.2	0.11	0.14	0.18	0.21
Cadmium	0.96	0.01	0.01	0.01	0.01
Chromium	321	0.00	0.00	0.00	0.00
Copper	102	0.01	0.01	0.01	0.02
Mercury	1.01	0.00	0.00	0.00	0.01
Lead	84	0.03	0.04	0.04	0.05
Zinc	219	0.01	0.01	0.02	0.02
Tributyltin	0.702	0.01	0.01	0.02	0.03
Dibutyltin	0.153	0.08	0.15	0.22	0.30
Monobutyltin	0.019	0.03	0.03	0.04	0.05
Total phosphorus					
Orthophosphate					
Nitrate nitrogen					
Ammonia nitrogen					
Total organic carbon					
Conductivity, mmhos/cm	29800				
pH	8.19				
DO	-				
Salinity, ppt	21.8				
% Moisture	102.1*				

\* Upper moisture content 102.1% in situ, 20% entrainment assumed. Equivalent milligrams water/liter dredged = 872.00; equivalent grams solids/liter dredged = 712.00.



Table 11

Estimated Mass Release for Lower Composite

<u>Parameter</u>	<u>Sediment Concentration mg/kg</u>	<u>Predicted Percentage Mass Loss for Effluent TSS Concentration</u>			
		<u>50 mg/l</u>	<u>100 mg/l</u>	<u>150 mg/l</u>	<u>200 mg/l</u>
Arsenic	5.4	0.03	0.04	0.06	0.07
Cadmium	0.37	0.11	0.21	0.30	0.40
Chromium	586	0.00	0.00	0.00	0.00
Copper	41	0.01	0.02	0.03	0.03
Mercury	0.53	0.00	0.00	0.00	0.00
Lead	23	0.07	0.10	0.13	0.16
Zinc	78	0.01	0.01	0.01	0.01
Tributyltin	0.035	0.13	0.26	0.39	0.51
Dibutyltin	0.0073	0.34	0.34	0.34	0.34
Monobutyltin	0.0018	0.37	0.70	0.99	1.29
Total phosphorus					
Orthophosphate					
Nitrate nitrogen					
Ammonia nitrogen					
Total organic carbon					
Conductivity, mmhos/cm	29,800				
pH	8.19				
DO	-				
Salinity, ppt	21.8				
% Moisture	37.3*				

\* Lower moisture content 37.3% in situ, 20% entrainment assumed. Equivalent milligrams water/liter dredged = 590.00; equivalent grams solids/liter dredged = 1,319.00.

Table 12  
Total Mass Release for Upper Composite

Parameter	Predicted Mass Loss, kg, for Effluent TSS Concentration			
	50 mg/l	100 mg/l	150 mg/l	200 mg/l
Arsenic	704	923	1,141	1,360
Cadmium	7	7	7	8
Chromium	350	393	437	480
Copper	360	652	944	1,236
Mercury	1	2	3	4
Lead	1,536	1,852	2,167	2,482
Zinc	1,200	1,763	2,326	2,889
Tributyltin	4	6	8	11
Dibutyltin	8	14	21	28
Monobutyltin	0	0	0	1
Total phosphorus	34,488	45,247	56,007	66,767
Orthophosphate	27,545	39,212	50,878	62,545
Nitrate nitrogen	12,590	12,590	12,590	12,590
Ammonia nitrogen	1,112,163	1,204,858	1,297,554	1,390,250
Total organic carbon	173,859	202,443	231,028	259,613
Conductivity, mmhos/cm				
pH				
DO				
Salinity, ppt	1.22E+09	1.22E+09	1.22E+09	1.22E+09
Upper cubic yards dredged	100,000			

Table 13  
Total Mass Release for Lower Composite

Parameter	Predicted Mass Loss, kg, for Effluent TSS Concentration			
	50 mg/l	100 mg/l	150 mg/l	200 mg/l
Arsenic	1,025	1,564	2,103	2,642
Cadmium	277	523	769	1,015
Chromium	3,271	5,510	7,749	9,988
Copper	2,466	4,762	7,057	9,353
Mercury	1	1	1	1
Lead	10,442	15,175	19,909	24,642
Zinc	3,568	3,568	3,568	3,568
Tributyltin	32	62	93	123
Dibutyltin	17	17	17	17
Monobutyltin	5	9	12	16
Total phosphorus	115,127	187,946	260,765	333,584
Orthophosphate	48,032	79,344	110,656	141,968
Nitrate nitrogen	114,384	114,384	114,384	114,384
Ammonia nitrogen	3,554,006	4,478,808	5,403,610	6,328,412
Total organic carbon	326,229	326,229	326,229	326,229
Conductivity, mmhos/cm				
pH				
DO				
Salinity, ppt	4.87E+09	4.87E+09	4.87E+09	4.87E+09
Lower cubic yards dredged	400,000			

discharged as effluent will meet all water quality criteria. The concentrations of dissolved arsenic will require a dilution of 7 to 1 (upper sediment) or 2 to 1 (lower sediment) in the mixing zone to meet the criteria.

The total mass release of contaminants as effluent was estimated to be generally less than 1 percent of the total contaminants placed, and varied with respect to the assumed concentration of TSS in the effluent. The placement operation should be managed to reduce the TSS concentration in the effluent to the greatest degree practical. This can be accomplished by the ponding of effluent water within the toe dikes prior to discharge. The resulting sedimentation of suspended solids should reduce the total mass release of contaminants.

The salinity of the effluent could potentially cause some adverse environmental impacts. A dilution of approximately 10 to 1 will reduce the salinity to less than 2 ppt and would minimize any impacts due salinity. Harding Lawson Associates indicated that water discharged from the Twitchell Island pump station will receive a minimum of 14:1 dilution at the edge of the zone of initial dilution upon entry into the San Joaquin River. Therefore, effluent water quality should not have a significant impact on receiving waters of San Joaquin River.

## PART IV: SURFACE RUNOFF TEST

### Background

Sediments removed from waterways by construction projects sometime contain high concentrations of contaminants such as heavy metals, PCBs, and PAHs. The potential for adverse environmental impacts from contaminants carried by surface runoff depends on several factors, including the chemical form of the contaminants and the type of disposal environment. Wet, unoxidized dredged material usually has a  $\text{pH} \geq 7$  with most contaminants tightly bound to the sediment particulates. Movement of contaminants from the disposal site by surface runoff would result primarily from erosion of sediment (Skogerboe et al. 1987). Suspended solids concentrations in surface runoff could range from 5,000 to 50,000 mg/l. Unfiltered (total) contaminant concentrations in surface runoff could also be very high, while filtered (dissolved) contaminant concentrations would be relatively low. When the dredged material is placed in an upland disposal environment, physicochemical changes occur as the material dries and oxidizes. These changes may significantly affect the surface runoff water quality, particularly the filtered contaminant concentrations. As the sediment dries and oxidizes, a hard surface crust forms which makes the sediment more resistant to erosion and decreases suspended solids to 10 to 1,000 mg/l. Unfiltered contaminant concentrations will decrease by several orders of magnitude, but filtered concentrations of some contaminants may increase. When the filtered concentration statistically equals the unfiltered concentration, most of the contaminant is dissolved rather than adsorbed to particulates (Skogerboe et al. 1987).

The prediction of surface runoff water quality from Corps of Engineers upland disposal sites is one of the evaluations described by Francingues et al. (1985) for the management of dredged material. The interpretation of the test data has been generally described in the decisionmaking framework of Lee et al. (1991). The WES developed a rainfall simulator/lysimeter system to predict surface runoff water quality from Corps project sites. The WES system is a rotating disk-type rainfall simulator modified from a design of Morin, Goldberg, and Seginer (1967) and Morin, Cluff, and Powers 1970. It incorporates the latest methods to accurately duplicate the drop size and terminal velocities of natural rainfall, factors which are critical in erosion and infiltration studies (Westerdahl and Skogerboe 1982). Extensive field

verification studies have been conducted with the WES Rainfall Simulator/Lysimeter System on a wide range of Corps project sites (Westerdahl and Skogerboe 1982, Lee and Skogerboe 1984, Skogerboe et al. 1987). The WES Rainfall Simulator/Lysimeter System has proved to be an effective tool for predicting surface runoff rates, soil loss, and contaminant concentrations.

This study was designed to predict potential surface runoff water quality from upland disposal of dredged material contaminated with heavy metals, PAHs, and tributyltin from the Oakland Harbor. Sediment was collected at two depths (upper and lower) from the proposed dredging site and tested using the WES Rainfall Simulator/Lysimeter System. Surface runoff water quality tests were conducted on the wet, unoxidized sediment and again 6 months later on air-dried and oxidized sediment. Runoff samples were analyzed for suspended solids, pH, conductivity, and contaminants. Test results were compared to the EPA Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987) and to the Effluent and Receiving Water Limitations for Waste Discharge issued by the CRWQCB in response to a permit application by the Port of Oakland for the disposal of Oakland Harbor sediment as levee-building material in the Sacramento River delta.

#### Methods and Materials

Two lysimeters (4.57 by 1.22 m) were filled to a depth of 0.33 m with sediment from two depths in Oakland Harbor. After thorough mixing, standing water on the sediment was decanted off the surface of each lysimeter. A composite sediment sample was collected from each lysimeter and analyzed for pH, electrical conductivity, arsenic, cadmium, chromium, copper, lead, mercury, zinc, PAHs, tributyltin, dibutyltin, and monobutyltin (USEPA 1986). Each sediment was then tested with the WES rainfall simulator using three 30-min storm events at 5.08 cm/hr on successive days (Figures 17-19) (Skogerboe et al. 1987). Runoff rates were measured every minute, and 4-l samples were collected for chemical analysis at 5, 15, and 25 min after the runoff began to occur. Additional samples were collected for suspended solids determinations at several additional points along the surface runoff hydrograph. The 4-l samples were combined into a composite sample for each test run and analyzed for filtered and unfiltered heavy metals, PAHs, and butyltins (USEPA 1984).

The lysimeters were then covered with semitransparent tops that allowed air movement over the surface of the sediment (Figure 13). After 6 months of



Figure 17. Rainfall simulation on anaerobic Oakland upper sediment



Figure 18. Runoff rate measurements were taken throughout the rainfall simulation



Figure 19. Soil bed of anaerobic Oakland upper sediment just after a simulated rainfall event

drying and oxidation (Figure 20), each sediment was sampled, and three storm events were conducted on each lysimeter. Storm events, sample collection, and sample analysis were the same as the wet stage tests. All analytical results are presented in Appendix C.

One-tailed t-tests were used to compare total and filtered surface runoff concentrations to the EPA Fresh and Marine Acute Water Quality Criteria for the Protection of Aquatic Life (USEPA 1987) and to the Effluent and Receiving Water Limitation Standards for dredging Oakland Harbor issued by the CRWQCB (Table 7). Contaminant concentrations less than or equal to the criteria were postulated as the null hypothesis. Contaminant concentrations greater than the EPA Criteria served as the alternate hypothesis. A rejection of the null hypothesis indicated that values were greater than the criteria.





Figure 20. Soil bed of dried and oxidized Oakland upper sediment prior to rainfall simulation

Statistical procedures were used to compare filtered (soluble) and unfiltered (total) contaminant concentrations in surface runoff from both the upper and lower sediments. The statistical tests were conducted using ANOVA procedure (SAS Institute Inc. 1988). The null hypothesis was that all concentrations for a particular contaminant were equal. The alternate hypothesis was that at least two contaminant concentrations were not equal. Actual contaminant concentrations that were statistically different were determined using the SAS Waller-Duncan Mean Separation Technique. All statistical tests were conducted at the  $P = 0.05$  level of significance. A detailed description of the tests is given by Winer (1971) and Sokal and Rohlf (1981).

## Results

### Wet, unoxidized surface runoff tests

Results of the sediment analysis are presented in Table 14. The sediments were moderately contaminated with arsenic, cadmium, chromium, copper, mercury, lead, zinc, and butyltins.

Suspended solids concentrations were 9,140 mg/l in surface runoff from the wet, unoxidized upper sediment and 2,920 mg/l from the lower sediment (Table 15). The suspended solids concentrations were not statistically different because of the large variability that normally occurs during this stage of the aging process. Surface runoff pH was 8.24 and 8.29 from the two sediments, and conductivity was 26.4 and 18.3 mV/cm for upper and lower sediments, respectively. Conductivity was statistically less in runoff from the lower sediment.

Results of the runoff tests showed that heavy metals in surface runoff from both the upper and lower sediments were mostly insoluble. Concentrations of filtered (soluble) metals were statistically lower than unfiltered (total) concentrations (Table 16). Concentrations of heavy metals were compared to the EPA Fresh and Marine Acute Maximum Criteria for the Protection of Marine Aquatic Life and to the Effluent and Receiving Water Limitation Standards issued for the Port of Oakland's permit application (Table 7). Most of the parameters determined in surface runoff unfiltered samples were statistically greater than at least one of the criteria, and several were statistically greater than all of the criteria. However, only copper and mercury concentrations were statistically greater than one criterion for filtered runoff samples from the upper sediment. Arsenic was the only parameter in surface runoff from the lower sediment that exceeded any of the criteria.

Concentrations of butyltins were significantly higher in unfiltered runoff samples from the upper sediment compared to the filtered samples and both unfiltered and filtered samples from the lower sediment (Table 16). Water quality criteria were available only for tributyltin, and only the unfiltered runoff samples from the upper sediment were statistically greater than the criteria.

Concentrations of PAHs in unfiltered runoff samples from the upper sediment were low (Table 17). The mean total PAH concentration was 89  $\mu\text{g/l}$  and was statistically greater than the Effluent Limitations criterion, which was 20  $\mu\text{g/l}$ . Past studies on other contaminated sediments showed that PAH

Table 14

Contaminant Concentrations (mg/kg) in Oakland Harbor Sediment

<u>Parameter</u>	<u>Upper Sediment</u>		<u>Lower Sediment</u>	
	<u>Wet</u> <u>Unoxidized</u>	<u>Dry</u> <u>Oxidized</u>	<u>Wet</u> <u>Unoxidized</u>	<u>Dry</u> <u>Oxidized</u>
Arsenic	10.2	13.9	5.4	7.7
Cadmium	0.96	0.61	0.37	0.45
Chromium	321	297	586	354
Copper	102	107	41	33
Mercury	1.01	0.953	0.536	0.130
Lead	84	71	23	15.3
Zinc	219	210	79	65
Tributyltin	0.702	0.188	0.035	0.003
Dibutyltin	0.153	0.060	0.007	0.0039
Monobutyltin	0.019	0.026	0.002	0.0033
Total Butyltin	0.874	0.277	0.044	0.010

Table 15

Surface Runoff Water Quality from Oakland Harbor Sediment

<u>Parameter</u>	<u>Upper, Wet</u> <u>Sediment</u>	<u>Upper, Dry</u> <u>Sediment</u>	<u>Lower, Wet</u> <u>Sediment</u>	<u>Lower, Dry</u> <u>Sediment</u>
Suspended solids (mg/l)**	9,140 A* (4,140-20,200)	970 B (439-2,140)	2,920 AB (1,320-6,450)	1,670 B (753-3,670)
pH	8.24 A (8.02-8.46)	7.69 B (7.47-7.91)	8.29 A (8.07-8.51)	7.09 C (6.87-7.31)
Electrical conductivity (mV/cm)	26.4 A (22.5-30.2)	4.25 C (0.39-8.12)	18.3 B (14.4-22.1)	2.20 C (0.00-6.07)

\* Mean concentrations followed by the same letter within each parameter were not statistically different.

\*\* Numbers in parentheses represent the 95-percent confidence interval about the mean.

Table 16  
Heavy Metal Concentrations in Surface Runoff  
from Oakland Harbor Sediments ( $\mu\text{g}/\ell$ )

Parameter	Wet		Dry	
	Unfiltered	Filtered	Unfiltered	Filtered
<u>Upper Sediment</u>				
Arsenic	36.5 A*,** (24.5-56.6)†	1.99 C (0.949-3.59)	1.90 C (0.768-3.74)	0.000 D (<DL††-0.639)
Cadmium	7.52 A**,‡,‡‡ (4.94-11.2)	0.228 D (<DL-0.761)	0.267 D (<DL-0.922)	0.423 CD (<DL-1.16)
Chromium	551 A**,‡,‡‡ (317-954)	0.868 BCD (0.078-2.24)	1.45 BCD (0.300-3.62)	0.332 CD (<DL-1.51)
Copper	516 A**,‡,‡‡,§ (299-890)	6.01 C§ (3.07-11.1)	47.6 B**,‡,‡‡,§ (24.9-90.1)	3.87 C (1.60-8.13)
Mercury	0.003 A (<DL-0.079)	0.091 A** (0.014-0.175)	0.113 A** (0.022-0.211)	0.027 A (<DL-0.118)
Lead	458 A**,‡,‡‡,§ (299-702)	0.850 DE (0.209-1.83)	42.1 B (25.4-69.5)	0.859 DE (0.137-2.04)
Zinc	1590 A**,‡,‡‡,§ (816-3110)	32.1 DE (16.0-63.7)	125 C (57.0-271)	47.4 CD (21.4-104)
Tributyltin	0.300 A**,‡‡ (0.220-0.386)	0.005 B (<DL-0.071)	0.051 B (<DL-0.056)	0.034 B (<DL-0.113)
Dibutyltin	0.086 A (0.057-0.115)	0.020 B (<DL-0.048)	0.024 B (<DL-0.056)	0.020 B (<DL-0.010)
Monobutyltin	<DL B (<DL-0.006)	<DL B (<DL-0.006)	0.013 A (0.007-0.020)	0.003 AB (<DL-0.010)
Total butyltin	0.384 A (0.284-0.492)	0.028 B (<DL-0.108)	0.094 B (0.004-0.193)	0.058 B (<DL-0.154)

(Continued)

- \* Mean concentrations followed by the same letter within each parameter were not statistically different.
- \*\* Mean concentration was statistically greater than the Receiving Water Limitation Standards.
- † Numbers in parentheses represent the 95-percent confidence interval about the mean.
- †† Detection limit.
- ‡ Mean concentration was statistically greater than the USEPA Fresh Water Acute Criteria.
- ‡‡ Mean concentration was statistically greater than the Effluent Limitation Standards.
- § Mean concentration was statistically greater than the USEPA Marine Water Criteria.

Table 16 (Concluded)

Parameter	Wet		Dry	
	Unfiltered	Filtered	Unfiltered	Filtered
<u>Lower Sediment</u>				
Arsenic	16.9 B* (9.95-28.4)	1.83 C* (1.83-3.64)	0.301 D (<DL-1.13)	<DL D (<DL-0.639)
Cadmium	3.77 B*,** (2.15-6.24)	0.209 D (<DL-0.834)	1.32 C (0.527-2.51)	0.423 CD (<DL-1.16)
Chromium	603 A**,†,†† (319-1,140)	1.09 BCD (0.107-2.94)	1.73 BC (0.446-4.14)	0.189 D (<DL-1.24)
Copper	278 A*,**,†,†† (148-522)	4.97 C (2.18-10.2)	55.8 B*,**,†,†† (29.3-106)	3.85 C (1.59-8.11)
Mercury	<DL A (<DL-0.089)	0.098 A (0.008-0.195)	0.024 A (<DL-0.114)	0.013 A (<DL-0.103)
Lead	329 A*,**,†,†† (201-539)	0.994 D (0.220-3.26)	54.0 B (32.6-88.8)	1.51 D (0.535-3.10)
Zinc	576 B*,**,†,†† (265-1,250)	35.9 D (16.0-78.8)	394 B*,**,†,†† (182-855)	68.4 CD (31.1-149)
Tributyltin	0.020 B (<DL-0.098)	0.003 B (<DL-0.080)	0.020 B (<DL-0.098)	0.010 B (<DL-0.087)
Dibutyltin	0.013 B (<DL-0.045)	0.044 AB (0.013-0.077)	0.010 B (<DL-0.042)	0.013 B (<DL-0.045)
Monobutyltin	0.003 AB (<DL-0.010)	0.003 AB (<DL-0.010)	0.003 AB (<DL-0.010)	<DL B (<DL-0.006)
Total butyltin	0.037 B (<DL-0.131)	0.055 B (<DL-0.150)	0.037 B (<DL-0.131)	0.027 B (<DL-0.120)

\* Mean concentration was statistically greater than the Receiving Water Limitation Standards.

\*\* Mean concentration was statistically greater than the Effluent Limitation Standards.

† Mean concentration was statistically greater than the USEPA Fresh Water Acute Criteria.

†† Mean concentration was statistically greater than the USEPA Marine Water Criteria.

Table 17  
PAH Concentrations in Surface Runoff Water ( g/l)

<u>Parameter</u>	<u>Mean Concentration</u>	<u>USEPA Marine Acute Criteria</u>	<u>USEPA Fresh Acute Criteria</u>	<u>Effluent Limitation</u>
Naphthalene	1.24 (0.277-2.94)*	2,350	2,300	--
2-methyl naphthalene	0.281 (<DL-0.828)	**	--	--
Acenaphthalene	0.533 (<DL-1.89)	--	--	--
Acenaphthene	0.768 (<DL-2.57)	970	1,700	--
Fluorene	1.15 (0.348-2.43)	--	--	--
Phenanthrene	4.89 (0.703-19.3)	--	--	--
Anthracene	2.00 (0.004-7.94)	--	--	--
Fluoranthene	11.9 (2.38-48.5)	40	3,980	--
Pyrene	20.3 (4.23-85.9)	--	--	--
Benzo(a)anthracene	3.03 (1.49-5.51)	--	--	--
Chrysene	6.08 (1.90-16.3)	--	--	--
Benzo(b)fluoranthene	9.23 (1.43-42.0)	--	--	--
Benzo(k)fluoranthene	4.46 (1.10-13.2)	--	--	--
Benzo(b)pyrene	9.52 (2.44-31.1)	--	--	--
Indeno(1,2,3,4)pyrene	6.65 (1.76-20.2)	--	--	--
Dibenzo(a,h)anthracene	1.04 (0.052-2.97)	--	--	--
Benzo(g,h,i)perylene	6.49 (5.28-7.91)	--	--	--
Total PAHs	89 (26.2-296)	300	--	20

\* Numbers in parentheses represent the 95-percent confidence interval about the mean.

\*\* No existing criteria.

concentrations in filtered samples from wet, unoxidized sediment were one to two orders of magnitude less than the unfiltered concentrations (Environmental Laboratory 1987). Filtered concentrations of PAHs in runoff from either of the Oakland Harbor sediments would, therefore, not have exceeded even the strictest criteria or standards.

#### Dry, oxidized surface runoff test

Concentrations of suspended solids in runoff samples from the dry, oxidized tests for the upper sediment were statistically less than concentrations in samples from the wet, unoxidized tests (Table 15). Concentrations were not statistically different between the dry, oxidized and wet, unoxidized tests conducted on the lower sediment. A hard crust formed on the surface of the upper sediment, reducing the erosiveness of the sediment and the resulting suspended solids concentrations. The lower sediment did not form the crust because of a substantially higher sand concentration. The runoff pH values of samples from the dry, oxidized tests were statistically less than samples from the wet, unoxidized tests, but were still greater than 7.0 for both sediments. Electrical conductivity in samples from the dry, oxidized tests was also statistically less than in samples from the wet, unoxidized tests.

Heavy metal concentrations in unfiltered runoff from the dry, oxidized sediments were also less than concentrations from the wet, unoxidized tests (Table 16). Filtered concentrations of cadmium, chromium, mercury, and zinc were not statistically different from unfiltered concentrations in samples collected in tests on the upper sediment. Filtered concentrations of arsenic, cadmium, mercury, and zinc were not statistically different from unfiltered concentrations in samples collected in tests on the lower sediment. Copper and mercury unfiltered concentrations in runoff samples collected from the upper sediment were statistically greater than at least one of the water quality criteria, but no parameters were statistically greater than any of the criteria for filtered samples. Copper and zinc unfiltered concentrations in runoff samples collected from the lower sediment were statistically greater than at least one of the water quality criteria, and none were statistically greater than the criteria for filtered samples.

Unfiltered butyltin concentrations were statistically less in runoff samples collected from the upper dry, oxidized sediment than in the wet, unoxidized sediment. Filtered butyltin concentrations in runoff samples from the upper dry, oxidized sediment or unfiltered and filtered concentrations from the lower dry, oxidized sediment were not statistically different from the

wet, unoxidized sediment. The tributyltin concentrations in samples from the dry, oxidized sediments were not statistically greater than any of the water quality criteria or standards.

Runoff samples from the dry, oxidized sediment were not analyzed for PAHs. Past studies on sediments contaminated with PAHs showed that concentrations of PAHs in runoff from dry, oxidized sediment would be significantly less than concentrations of PAHs in unfiltered samples from wet, unoxidized sediment. Unfiltered PAH concentrations from the wet, unoxidized upper sediment were very close to the strictest criteria or standards. Consequently, all other samples would not have been significantly greater than the criteria or standards.

### Discussion

Changes did occur in the sediment during the drying and oxidation process, and surface runoff water quality was significantly affected. Surface runoff pH levels were statistically lower after the sediment had dried and oxidized; however, the pH level remained above 7.0 for both the upper and lower sediment. This contrasts with most other sediments tested at the WES, where pH levels in runoff from dry, oxidized sediments ranged from 5.0 to 6.5. These results of little change in soil pH after drying and oxidation, agrees with field observations by Patrick (1990), who only found 5 percent of field collected sediment samples at pH 5.0 while 95 percent of the samples were pH 7.0 after Oakland sediment was placed on Twitchell Island's levee. Initially the upper sediment was the most erosive; however, the two sediments were not statistically different after drying and oxidation. Electrical conductivity was high in runoff from both wet, unoxidized sediments but was statistically reduced after drying and oxidation.

Concentrations of heavy metals in surface runoff were highest in unfiltered samples collected from the wet, unoxidized upper sediment. Filtered concentrations in runoff from the two sediments, however, were not statistically different. Heavy metal, in runoff, except for mercury, were primarily insoluble and bound to the suspended solids in the wet, unoxidized sediments. Mercury concentrations were close to or less than the detection limits where analytical variability was relatively high and statistical differences were not detected. Tributyltin concentrations were highest in the unfiltered runoff from the wet, unoxidized upper sediment, but filtered concentrations were



not statistically different between the sediments. Tributyltin was primarily insoluble and bound to the suspended solids in both wet, unoxidized sediments.

After drying and oxidation, concentrations of heavy metals in unfiltered surface runoff samples from both sediments were statistically reduced. Concentrations of cadmium, chromium, copper, lead, and zinc in filtered samples, however, were not statistically reduced by the drying and oxidation process. Heavy metals in runoff from both the sediments were more soluble after drying and oxidation; however, a significant portion of the heavy metals in surface runoff remained bound to the particulates. Tributyltin was primarily dissolved in runoff from both sediments.

Most heavy metal concentrations were statistically greater than one or more of the water quality criteria or standards in unfiltered samples from the wet, unoxidized sediments (Table 18). Tributyltin concentrations in unfiltered runoff from the upper sediment also exceeded the Effluent and Receiving Water Limitation water quality standards. Only mercury concentrations in the upper sediment filtered runoff samples and arsenic concentrations in lower sediment filtered runoff were significantly greater than the Receiving Water Limitation standards. The difference was, however, less than an order of magnitude. Several heavy metal parameters in unfiltered runoff samples from both dry, oxidized sediments were statistically greater than one or more of the criteria or standards. Tributyltin concentrations, however, were not statistically greater than any of the criteria or standards. No parameters in filtered samples from either of the dry, oxidized sediments exceeded any of the criteria or standards.

#### Surface Runoff Impacts and Controls

Contaminants in surface runoff from the upper and lower Oakland Harbor sediments were mostly bound to the sediment particulates. Significant quantities of arsenic, cadmium, chromium, copper, lead, zinc, and tributyltin could be eroded from an upland disposal site during the wet, unoxidized stage if the suspended solids were not removed from the runoff. Generally, surface runoff from the upper sediment contained slightly higher concentrations of contaminants, particularly tributyltin, arsenic, and zinc. Removal of suspended solids from runoff would eliminate contaminant migration offsite.

Potential surface runoff water quality problems during the wet, unoxidized period of upland disposal would be primarily associated with erosion of

Table 18  
Surface Runoff Contaminants Exceeding  
Water Quality Criteria or Standards

<u>Test</u>	<u>USEPA Marine Acute Criteria</u>	<u>USEPA Fresh Acute Criteria</u>	<u>Effluent Limitation Standards</u>	<u>Receiving Water Limitation Standards</u>
<u>Upper Sediment</u>				
Unfiltered, wet, unoxidized	Copper Lead Zinc	Cadmium Chromium Copper Lead Zinc	Cadmium Chromium Copper Lead Zinc Tributyltin PAHs	Arsenic Cadmium Chromium Copper Lead Zinc Tributyltin
Filtered, wet, unoxidized	Copper	none	none	Mercury
Unfiltered, dry, oxidized	Copper Mercury	Copper	Copper	Copper Mercury
Filtered, dry, oxidized	none	none	none	none
<u>Lower Sediment</u>				
Unfiltered, wet, unoxidized	Copper Lead Zinc	Chromium Copper Lead Zinc	Cadmium Chromium Copper Lead Zinc	Arsenic Cadmium Chromium Copper Lead Zinc
Filtered, wet, unoxidized	none	none	none	Arsenic
Unfiltered, dry, oxidized	Copper Zinc	Copper Zinc	Copper Zinc	Copper Zinc
Filtered, dry, oxidized	none	none	none	none

particulates. Management of the upland disposal site to remove particulates from surface runoff would remove 90 to 99 percent of all contaminants in surface runoff. Only soluble copper concentrations exceeded the EPA marine water quality criteria and soluble arsenic and mercury exceeded the Receiving Water Limitation standards issued by the CRWQCB. Consideration of a mixing zone at the discharge point from the upland disposal site and/or further treatment may be required for those soluble contaminants. A mixing zone ratio of less than 10 to 1 (receiving water to runoff water) would be required to dilute contaminant concentrations in surface runoff water to the required criteria.

If surface runoff, however, were discharged into a freshwater environment, salinity could cause some adverse environmental impacts. A dilution ratio of 10 parts fresh water to 1 part runoff would reduce the electrical conductivity of the runoff to less than 5 mV/cm and should minimize any impacts due to salinity. The dilution could be accomplished by the mixing of runoff from approximately 10 acres of freshwater, uncontaminated areas with runoff from each acre of dredged material disposal site. This appears to be easily achieved after consideration of the large drainage area of Twitchell Island and the relatively small area of levees. In addition, the pumped discharge from the island is quickly diluted upon discharge into the San Joaquin River (Figures 21-23).

Potential problems in surface runoff from dry, oxidized sediments should occur only from copper, mercury, and zinc bound to the suspended solids. Consideration of a mixing zone or removal of the suspended solids should eliminate the need for further restrictions, particularly with regard to treatment of soluble contaminants. A mixing zone of less than 10 to 1 would be required to dilute unfiltered contaminant concentrations to less than or equal to the Receiving Water Limitation standards. In addition to the mixing of surface runoff from 1 acre of dredged material with 10 acres of uncontaminated surface runoff mentioned above, a mixing zone appears to be available in the San Joaquin River from the Twitchell Island discharge pipe (Figure 23). Harding Lawson Associates indicated that drainage water discharged from Twitchell Island will receive a minimum 14:1 dilution upon entry into the San Joaquin River. Therefore, surface runoff water quality should not have a significant impact on receiving waters of San Joaquin River. Establishment of vegetation either by natural succession or by planting would further reduce contaminant concentrations in surface runoff.



Figure 21. View of agricultural fields on the interior of Twitchell Island (drainage ditch pump shown in lower right corner)



Figure 22. Discharge pump that pumps surface water out of drainage ditch from the interior of Twitchell Island



Figure 23. Twitchell Island drainage water is discharged through a pipe into the San Joaquin River

## PART V: LEACHATE TEST

### Methods and Materials

#### Oxidized sediment preparation

The sediment used in aerobic testing was first placed into 38-ℓ glass aquariums to a depth of approximately 6 cm. The sediment was allowed to oxidize at ambient temperature. Each week the sediment was thoroughly mixed to expose fresh sediment surfaces to the air. When necessary, deoxygenated distilled-deionized (DDI) water was added to the sediment to maintain a moist condition. At the end of 6 months, the sediment was thoroughly mixed before being used in testing.

#### Kinetic batch testing

Batch testing was performed to determine shaking time necessary to achieve equilibrium or steady-state conditions for metals and butyltin leachate concentrations. The general experimental sequence is presented in Table 19.

For testing metal releases from anaerobic upper and lower Oakland Harbor sediments, triplicate 250-ml polycarbonate centrifuge tubes fitted with a leakproof, airtight top were each loaded with 200 g of sediment and deoxygenated DDI water at a 4:1 water-to-sediment dry weight ratio. All operations were conducted in a glove box under a nitrogen atmosphere (Figure 24). Twenty-four centrifuge tubes were loaded to allow triplicate sampling at 6 hr, and at 1, 2, 3, 4, 7, 10, and 14 days. Samples were placed horizontally on a reciprocating shaker at 160 strokes per minute for the allotted time. Three tubes for each sediment (Oakland Harbor upper and lower sediment) were removed from the shaker and centrifuged at 9,000 rpm ( $13,000 \times g$ ) for 30 min. The supernatant was filtered under a nitrogen atmosphere through 0.45- $\mu$ m membrane filters (Figure 25). The filtrate was acidified to pH 1 with concentrated Ultrex nitric acid and stored in plastic bottles until analyzed.

For testing metal releases from aerobic upper and lower Oakland Harbor sediments, triplicate 250-ml polycarbonate centrifuge tubes were each loaded with 200 g of aerobic sediment. Shaking, sampling, filtration, and sample handling for this test were identical to the procedures described in the preceding paragraph with the exception that testing was conducted under ambient atmosphere rather than under a nitrogen atmosphere, and sampling intervals were 1, 2, 4, and 7 days.

Table 19

Experimental Sequence for Determining Appropriate Shaking Times  
for Anaerobic Kinetic Testing of Oakland Harbor Sediment

---

Step 1	PLACE SEDIMENT IN APPROPRIATE CENTRIFUGE TUBE (STAINLESS STEEL OR POLYCARBONATE), ADD SUFFICIENT DEOXYGENATED DDI WATER TO MAINTAIN WATER-TO-SEDIMENT RATIO OF 4:1.
--------	---

---

Step 2	PLACE CENTRIFUGE TUBES FOR METALS ON RECIPROCATING SHAKER AND SHAKE AT 160 CYCLES PER MINUTE. PLACE CENTRIFUGE TUBES FOR TRIBUTYLTIN IN ROTARY MIXER AND TURN AT 40 REVOLUTIONS PER MINUTE.
--------	---

---

Step 3	REMOVE TUBES (ENOUGH FOR TRIPPLICATE SAMPLES) FROM SHAKER AT APPROPRIATE INTERVALS: 1 AND 2 DAYS FOR TRIBUTYLTIN, AND 6 HR, 1, 2, 3, 4, 7, 10, AND 14 DAYS FOR METALS.
--------	--

---

Step 4	CENTRIFUGE FOR 30 MINUTES AT $6,500 \times g$ FOR TRIBUTYLTIN AND $9,000 \times g$ FOR METALS.
--------	--

---

Step 5	FILTER CENTRIFUGED LEACHATE THROUGH A $0.45\text{-}\mu\text{m}$ PORE SIZE MEMBRANE FILTER FOR METALS, AND THROUGH A WHATMAN GF/D GLASS-FIBER PREFILTER AND A GELMAN AE GLASS-FIBER FILTER WITH A $1\text{-}\mu\text{m}$ NOMINAL PORE SIZE FOR TRIBUTYLTIN.
--------	--

---

Step 6	ACIDIFY LEACHATE FOR METALS ANALYSIS WITH ULTREX NITRIC ACID. STORE SAMPLES FOR ANALYSIS OF TRIBUTYLTIN IN GLASS BOTTLES AND FREEZE UNTIL ANALYSIS. STORE LEACHATE FOR METALS ANALYSIS IN PLASTIC BOTTLES.
--------	--

---

Kinetic testing for tributyltin in anaerobic Oakland upper and lower sediment was conducted in specially fabricated 450-ml stainless steel centrifuge tubes (Figure 26). Twenty-one centrifuge tubes (sufficient for three replicates), double-rinsed with acetone, were loaded with sufficient sediment and deoxygenated DDI water to obtain a 4:1 water-to-sediment dry weight ratio. The total mass (approximately 350 g) of sediment and water was adjusted to allow the tube to be safely centrifuged at 6,200 rpm ( $6,500 \times g$ ). All operations were conducted under a nitrogen atmosphere. The tubes were placed in a rotary tumbler and turned end over end at 40 rpm for periods of 24 and 48 hr. At the appointed times, the samples were removed from the tumbler and





Figure 24. Anaerobic sediments are leached under a nitrogen atmosphere in a glove box

centrifuged for 30 min. Resulting supernatants were filtered through a Whatman GF/D prefilter and a Gelman AE filter with a nominal pore size of 1.0  $\mu\text{m}$ . Whatman GF/D prefilters and Gelman AE filters are binderless, glass-fiber filters that generally do not contain detectable quantities of organic contaminants. As a precaution against contamination, the filters used in this study were combusted at 400 °C prior to use. Filtration was conducted under a nitrogen atmosphere; samples were frozen immediately in acetone-rinsed 2-l glass bottles until analyzed.

#### Sequential batch testing

A 4:1 water-to-sediment ratio and a shaking time of 24 hr were used in the sequential batch leach tests for Oakland Harbor sediments. General test procedures for assessing steady-state leachate and sediment metal and tributyltin concentrations are outlined in Table 20. Sequential batch tests for



Figure 25. Filtering of anaerobic sediment leachates is performed in a nitrogen atmosphere



Figure 26. Centrifuge tubes with anaerobic sediment are stored under a nitrogen atmosphere

Table 20

Test Sequence for Sequential Batch Leaching of Anaerobic Oakland  
Harbor Sediment for Metals and Tributyltin

---

Step 1	LOAD SEDIMENT INTO APPROPRIATE CENTRIFUGE TUBES: 250-ML POLYCARBONATE FOR METALS AND 450-ML STAINLESS STEEL FOR TRIBUTYLTIN. ADD SUFFICIENT WATER TO EACH TUBE TO BRING FINAL WATER-TO-SEDIMENT RATIO TO 4:1. LOAD SUFFICIENT NUMBER OF STAINLESS STEEL TUBES TO OBTAIN SUFFICIENT LEACHATE FOR ANALYSIS.
--------	---

---

Step 2	PERFORM STEP 2 DESCRIBED IN TABLE 19.
--------	---------------------------------------

---

Step 3	CENTRIFUGE FOR 30 MIN AT 6,500 $\times$ g FOR TRIBUTYLTIN AND 9,000 $\times$ g FOR METALS.
--------	--

---

Step 4	FILTER LEACHATE THROUGH 0.45- $\mu$ m MEMBRANE FILTERS FOR METALS OR THROUGH WHATMAN GD/F GLASS-FIBER PREFILTERS FOLLOWED BY GELMAN AE GLASS-FIBER FILTERS OF 1.0- $\mu$ m NOMINAL PORE SIZE FOR TRIBUTYLTIN. SET ASIDE A SMALL AMOUNT OF LEACHATE PRIOR TO ACIDIFICATION FOR ANALYSIS OF pH, CONDUCTIVITY, AND TOTAL ORGANIC CARBON.
--------	---

---

Step 5	RETURN TO STEP 2 AFTER REPLACING LEACHATE WITH DEOXYGENATED DDI WATER. REPEAT THE ENTIRE PROCEDURE THE DESIRED NUMBER OF TIMES.
--------	---

---

Notes: Testing sequence is the same for aerobic sediments except that anaerobic integrity is not maintained.

---

metals under anaerobic conditions were conducted in triplicate 250-ml polycarbonate centrifuge bottles with leakproof caps. Each centrifuge tube was loaded under a nitrogen atmosphere with anaerobic Oakland Harbor (upper or lower) sediment and deoxygenated DDI water to a 4:1 water-to-sediment ratio. Tubes were mechanically shaken for 24 hr and centrifuged at 9,000  $\times$  g for 30 min. Most of the leachate from each 250-ml centrifuge bottle was filtered through a 0.45- $\mu$ m membrane filter. The unfiltered leachate was analyzed for pH using a combination electrode and a millivolt meter and for conductivity using a Yellow Springs Instrument Company conductivity meter and cell. Fresh deoxygenated DDI water was added to replace the leachate removed for analysis. The procedure described above for sequentially contacting anaerobic Oakland Harbor sediment with clean water was repeated seven times. The same general

procedure was repeated for aerobic batch leach tests for metals, except that anaerobic conditions were not maintained.

Testing of Oakland Harbor sediment for butyltin compounds was conducted as described for metals except that 450-ml stainless steel centrifuge tubes were used. Filtration procedures used for butyltin compounds were as previously described for butyltin kinetic batch testing. A subsample of filtered leachate was set aside from both the anaerobic and aerobic tests for analysis of total organic carbon. After each cycle, the sediment was remixed with DDI water, shaken for 24 hr, and then processed as previously described. Three replicates were taken through six leach cycles for the anaerobic testing and five leach cycles for the aerobic testing.

#### Interstitial water extraction

Interstitial water samples for analysis of metals and butyltin compounds were obtained by centrifugation of anaerobic upper and lower Oakland Harbor sediments. To obtain samples for metals, triplicate 250-ml polycarbonate centrifuge tubes fitted with a leakproof, airtight top were loaded with sediment in a glove box under a nitrogen atmosphere. The tubes were centrifuged at  $9,000 \times g$  for 30 min, and the supernatant was filtered under a nitrogen atmosphere through a  $0.45\text{-}\mu\text{m}$  pore size membrane filter. The filtrate was acidified to pH 1 with concentrated Ultrex grade nitric acid and stored in plastic bottles until analyzed.

Interstitial water for analysis of butyltin compounds was obtained by centrifugation of anaerobic sediments in 450-ml stainless steel centrifuge tubes. Six tubes were loaded with sediment, centrifuged for 30 min at  $6,500 \times g$ , and filtered through Whatman GF/D glass-fiber prefilters and Gelman AE glass-fiber filters with a nominal pore size of  $1.0\text{ }\mu\text{m}$ . All steps in the operation were conducted under a nitrogen atmosphere. Following filtration, the interstitial water was placed in 2- $\ell$  glass bottles and immediately frozen until analyzed.

#### Chemical analysis

Leachate and sediment samples were analyzed by Battelle Northwest for tributyltin, dibutyltin, monobutyltin, mercury, arsenic, zinc, cadmium, chromium, and copper.

#### Statistical analysis

All statistical analyses were conducted using methods developed by the Statistical Analysis Systems Institute (Barr et al. 1976). To test for differences between means, ANOVA procedures were used.

## Results

### Kinetic batch testing

Kinetic batch testing was performed to confirm previous experiments indicating that a 24-hr shaking time was sufficient to achieve steady-state conditions. Results for metals and butyltin compounds in anaerobic Oakland Harbor upper sediments are presented in Table 21. Results show that peak levels of leachate Hg, tributyltin, and dibutyltin were obtained following 1 day of shaking (no difference at the  $P < 0.05$  level). One day of shaking for these compounds will, therefore, reflect the highest leachate concentrations observable. Arsenic leachate concentrations following 1 day of shaking were statistically ( $P < 0.05$ ) equivalent to all but the 4-day concentration. Zinc concentrations following 1 day of shaking were exceeded only by concentrations following 7 days. Chromium concentrations following 1 day of shaking were lower than at any time period, except 6 hr and 4 days. Copper concentrations following 1 day were not different from any but the 10- and 14-day concentrations. Cadmium was detected only in the day 7 leachate. Monobutyltin data for days 1 and 2 did not differ.

Kinetic testing results for metals and butyltin compounds in anaerobic Oakland Harbor lower sediment are presented in Table 22. Results showed that leachate Cd, Cu, Hg, Zn, tributyltin, dibutyltin, and monobutyltin concentrations following 1 day of shaking did not differ statistically at  $P = 0.05$  from leachate concentrations at later sampling periods. These results indicated that steady-state concentrations of these metals had been reached in 1 day. Only As and Cr exhibited higher leachate concentrations at sampling times of 2 days or more.

Kinetic testing results for metals in aerobic Oakland Harbor upper sediment are presented in Table 23. Kinetic testing for butyltin compounds were not conducted for aerobic sediment. Results showed that leachate metal concentrations for As, Cr, and Hg following 1 day of shaking did not differ statistically at  $P = 0.05$  from leachate metal concentrations following 2, 4, or 7 days of shaking. These results indicated that steady-state concentrations of these metals had been reached in 1 day. Leachate concentrations of Cd and Zn following 1, 2, and 4 days of leaching were lower than their respective concentrations following 7 days of shaking, indicating that steady-state concentrations of these metals were achieved only after more prolonged shaking.

Table 21

Heavy Metal\* and Butyltin\*\* Concentrations in Anaerobic Oakland (Upper)  
Harbor Leachate at Different Sampling Times

Parameter	Sampling Time									
	6 Hr	Day 1	Day 2	Day 3	Day 4	Day 7	Day 10	Day 14		
As	0.0513 (0.002)	0.0593 (0.004)	0.0980 (0.005)	0.1110 (0.011)	0.1533 (0.045)	0.0713 (0.004)	0.0670 (0.005)	0.0867 (0.006)		
Cd	<0.069	<0.069	<0.069	<0.069	<0.069	0.00017	<0.069 (0.0009)	<0.069		
Cr	0.0010 (0.0001)	0.0012 (0.0002)	0.0024 (0.0007)	0.0025 (0.0002)	0.0020 (0.0003)	0.0032 (0.0002)	0.0023 (0.0001)	0.0040 (0.0004)		
Cu	0.0022 (0.0003)	0.0033 (0.002)	0.0017 (0.0004)	0.0017 (0.0002)	0.0013 (0.0002)	0.0040 (0.0005)	0.0007 (0.0003)	0.0007 (0.0003)		
Hg	0.000027 (0.000009)	0.000059 (0.00003)	0.000009 (0.000005)	0.000011 (0.000003)	0.000002 (0.000002)	0.000012 (0.000003)	0.000003 (0.000002)	0.000017 (0.000006)		
Zn	0.0427 (0.013)	0.0345 (0.008)	0.0260 (0.002)	0.0262 (0.003)	0.0224 (0.003)	0.1054 (0.013)	0.0240 (0.003)	0.0262 (0.0009)		
Tributyltin	NT†	0.0098 (0.003)	0.0153 (0.002)	NT	NT	NT	NT	NT		
Dibutyltin	NT	0.0057 (0.002)	0.0082 (0.002)	NT	NT	NT	NT	NT		
Monobutyltin	NT	0.0014 (0.001)	0.0259 (0.022)	NT	NT	NT	NT	NT		

\* Expressed in milligrams per liter (standard error in parentheses).

\*\* Expressed in micrograms per liter (standard error in parentheses).

† Not tested.

Table 22

Heavy Metal\* and Butyltin\*\* Concentrations in Anaerobic Oakland  
(Lower) Harbor Leachate at Different Sampling Times

Parameter	6 Hr	Sampling Time							
		Day 1	Day 2	Day 3	Day 4	Day 7	Day 10	Day 14	
As	0.0163 (0.002)	0.0227 (0.0007)	0.0440 (0.004)	0.0547 (0.007)	0.0567 (0.004)	0.0730 (0.009)	0.1023 (0.004)	0.0867 (0.004)	
Cd	0.0005 (0.0005)	0.00007 (0.00004)	0.0002 (0.0001)	<0.069	0.00005 (0.00003)	0.0003 (0.0001)	<0.069	<0.069	
Cr	0.0004 (0.0001)	0.0005 (0.00002)	0.0001 (0.0002)	0.0009 (0.00009)	0.0011 (0.00004)	0.0011 (0.0001)	0.0015 (0.0001)	0.0024 (0.00003)	
Cu	0.0023 (0.0004)	0.0033 (0.002)	0.0009 (0.0004)	0.0013 (0.0007)	0.0022 (0.0002)	0.0020 (0.0003)	0.0007 (0.0007)	0.0007 (0.0003)	
Hg	0.00010 (5.0E6)	0.00010 (0.00002)	0.00012 (0.00003)	0.000075 (0.00003)	0.00043 (0.0004)	0.00014 (0.00002)	0.000026 (0.00005)	0.000013 (0.000006)	
Zn	0.0435 (0.012)	0.0253 (0.006)	0.0491 (0.014)	0.0284 (0.006)	0.0376 (0.003)	0.0427 (0.005)	0.0238 (0.0004)	0.0473 (0.011)	
Tributyltin	NT†	0.0180 (0.0006)	0.0137 (0.0003)	NT	NT	NT	NT	NT	
Dibutyltin	NT	0.0130 (0.000)	0.0020 (0.001)	NT	NT	NT	NT	NT	
Monobutyltin	NT	0.0079 (0.001)	0.0827 (0.052)	NT	NT	NT	NT	NT	

\* Expressed in milligrams per liter (standard error in parentheses).

\*\* Expressed in micrograms per liter (standard error in parentheses).

† Not tested.

Table 23  
Heavy Metal Leachate Concentrations [mg/l (Standard Error)]  
in Aerobic Oakland (Upper) Harbor Sediment at  
Different Sampling Times

<u>Metal</u>	<u>Sampling Time</u>			
	<u>Day 1</u>	<u>Day 2</u>	<u>Day 4</u>	<u>Day 7</u>
As	0.0012 (0.0006)	0.0009 (0.0005)	0.0016 (0.0002)	0.0011 (0.0005)
Cd	0.0010 (0.0002)	0.0009 (0.00003)	0.0016 (0.0004)	0.0020 (0.0002)
Cr	0.0018 (0.0001)	0.0032 (0.002)	0.0014 (0.00001)	0.0012 (0.00002)
Cu	0.0120 (0.0005)	0.0154 (0.0002)	0.0178 (0.0004)	0.0228 (0.0003)
Hg	0.000024 (0.000003)	0.000026 (0.000003)	0.000005 (0.000002)	0.000015 (0.000007)
Zn	0.0233 (0.002)	0.0253 (0.002)	0.0267 (0.002)	0.0380 (0.005)

Leachate Cu concentrations following 1 day of leaching were slightly lower than concentrations at later sampling times.

Kinetic testing results for metals in aerobic Oakland Harbor lower sediments are summarized in Table 24. Results showed that leachate metal concentrations for Cd, Zn, and Hg following 1 day of shaking did not differ statistically at  $P = 0.05$  from leachate metal concentrations following 2, 4, or 7 days of shaking, indicating that steady-state concentrations of these metals had been reached in 1 day. Batch test data for these metals, therefore, reflected worst-case concentrations. Leachate As concentrations were below detection limits at all sampling times. Leachate Cu concentrations following 1, 2, and 4 days of leaching were lower than Cu concentrations following 7 days of shaking. Chromium leachate concentrations following 2, 4, and 7 days of shaking were slightly higher than Cr leachate concentrations following 1 day of shaking. In past leaching studies with sediments from Indiana Harbor, Indiana (Environmental Laboratory 1987), and Everett Harbor, Washington (Palermo et al. 1989), 1 day was sufficient for steady-state or



Table 24  
Heavy Metal Leachate Concentrations [mg/l (Standard Error)]  
in Aerobic Oakland (Lower) Harbor Sediment at  
Different Sampling Times

<u>Metal</u>	<u>Day 1</u>	<u>Day 2</u>	<u>Day 4</u>	<u>Day 7</u>
As	<0.00095	<0.00095	<0.00095	<0.00095
Cd	0.0021 (0.00001)	0.0021 (0.0001)	0.0019 (0.0003)	0.0022 (0.0002)
Cr	0.0008 (0.00004)	0.0011 (0.00003)	0.0011 (0.00001)	0.0015 (0.00006)
Cu	0.0057 (0.0004)	0.0058 (0.0003)	0.0070 (0.0005)	0.0076 (0.0006)
Hg	0.000009 (0.000001)	0.000006 (0.0000006)	0.000004 (0.0000008)	0.000004 (0.0000003)
Zn	0.0700 (0.002)	0.0647 (0.004)	0.0570 (0.010)	0.0637 (0.003)

worst-case metal concentrations to be achieved. Metals in Oakland Harbor sediment deviated slightly from this kinetic behavior because of time of sediment-water contact, sediment salinity, and sediment oxidation status (Brannon, Myers, and Price 1990).

#### Sequential batch leaching

General leachate quality. Leachate pH and conductivity values for anaerobic and aerobic sequential batch leaching tests for Oakland Harbor sediments are presented in Table 25. During anaerobic leaching, pH was 1 to 2 units higher than during aerobic leaching from Oakland Harbor upper sediment. This resulted from an approximately 2-pH unit rise during anaerobic testing. Initial (cycle 1) anaerobic and aerobic leachate pH values were similar. Oxidation of Oakland Harbor lower sediment resulted in a decrease of approximately 1 pH unit, which was maintained during subsequent sequential batch tests.

Initial conductivities of oxidized sediments were lower than those measured in either anaerobic Oakland Harbor upper or lower sediments (Table 25). The upper sediment was also higher in conductivity than the lower sediment. Conductivity decreased as leaching proceeded, reaching relatively constant



values by the fifth leach cycle. This reflected a washout of salts during the course of leaching.

Metal releases. No statistically significant regression existed between steady-state sediment and leachate concentrations for any of the metals or butyltin compounds tested in either Oakland Harbor upper or lower sediment. Therefore, distribution coefficients describing the partitioning of metals and butyltin between sediment and water could not be obtained. Steady-state metal concentrations in sediment and leachate obtained from the sequential batch leaching tests for anaerobic Oakland Harbor upper sediment are presented in Tables 26 and 27, respectively. Leachate concentrations of Cd, Cr, and Zn exhibited concentration peaks in the third leach cycle, then decreased in concentration. Copper exhibited a peak in the third and sixth leach cycles. Arsenic and Hg concentrations remained relatively unchanged over the course of the sequential leaching test. Steady-state metal concentrations in sediment and leachate obtained from the sequential batch leaching tests for anaerobic Oakland Harbor lower sediment are presented in Tables 28 and 29, respectively. Leachate concentrations of all metals tested, except for Hg, peaked during the third leach cycle.

Sediment and leachate metal concentrations obtained from the sequential batch leaching tests for aerobic Oakland Harbor upper sediment are presented in Tables 30 and 31, respectively. Leachate concentrations of As and Cu peaked in the third leach cycle; Cd and Hg were relatively unchanged. Chromium and Zinc peaked at the third and fifth leach cycles. Metal concentrations in sediment and leachate for aerobic Oakland Harbor lower sediment are presented in Tables 32 and 33, respectively. Steady-state leachate concentrations of Cd peaked in the first leach cycle, Cr and Zn peaked in the third and fourth leach cycles, Cu in the fourth leach cycle, and As in the fifth leach cycle. Mercury concentrations did not change over time. Metal leachate concentrations during sequential batch leaching of anaerobic and aerobic Oakland Harbor sediments are presented in Figures 27-29 for As, Cu, and Zn, respectively. The peaks in leachate concentration following the first two leach cycles (days), described in the preceding discussion of sequential batch leaching of metals, are evident in these data.

Butyltin releases. Oxidation of sediments from Oakland Harbor did not result in statistical differences in sediment butyltin concentrations. Therefore, initial butyltin sediment concentrations were used because of the

Table 26

Steady-State Heavy Metal Sediment Concentrations\*  
in Anaerobic Oakland (Upper) Harbor Sediment

<u>Metal</u>	<u>Cycle Number</u>						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
As	10.08 (0.025)	9.95 (0.023)	9.74 (0.047)	9.62 (0.053)	9.53 (0.052)	9.40 (0.056)	9.27 (0.067)
Cd	0.959 (0.0002)	0.978 (0.0004)	0.952 (0.002)	0.949 (0.0003)	0.946 (0.003)	0.943 (0.003)	0.940 (0.004)
Cr	321.29 (0.0006)	321.27 (0.001)	321.50 (0.027)	320.20 (0.023)	320.09 (0.024)	319.88 (0.035)	319.73 (0.047)
Cu	102.49 (0.001)	102.44 (0.004)	101.42 (0.015)	100.55 (0.119)	99.99 (0.127)	98.75 (0.099)	98.00 (0.059)
Hg	1.0119 (0.000005)	1.0119 (0.0001)	1.0117 (0.00005)	1.0118 (0.00004)	1.0118 (0.00005)	1.0117 (0.00007)	1.0117 (0.00007)
Zn	218.22 (0.007)	218.14 (0.008)	217.44 (0.090)	217.04 (0.090)	216.77 (0.069)	216.41 (0.058)	216.12 (0.058)

\* Expressed in micrograms per gram (standard error in parentheses).

Table 27

Heavy Metal Concentrations\* in Leachate from  
Anaerobic Oakland (Upper) Harbor Sediment

<u>Metal</u>	<u>Cycle Number</u>						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
As	0.0323 (0.006)	0.0297 (0.002)	0.0527 (0.006)	0.0310 (0.002)	0.0213 (0.002)	0.0330 (0.002)	0.0330 (0.008)
Cd	0.0003 (0.00005)	0.0002 (0.00004)	0.0014 (0.0005)	0.0007 (0.0003)	0.0007 (0.00004)	0.0009 (0.00003)	0.0007 (0.00009)
Cr	0.0024 (0.0002)	0.0065 (0.00009)	0.1905 (0.007)	0.0751 (0.004)	0.0272 (0.0004)	0.0546 (0.003)	0.0368 (0.005)
Cu	0.0026 (0.003)	0.0128 (0.0007)	0.2546 (0.004)	0.2177 (0.027)	0.1390 (0.005)	0.3119 (0.009)	0.1876 (0.010)
Hg	0.000007 (0.000001)	0.000006 (0.000002)	0.00002 (0.000009)	0.00001 (0.000003)	0.000007 (0.000003)	0.00002 (0.000008)	0.00002 (0.000005)
Zn	0.0200 (0.002)	0.0190 (0.001)	0.1767 (0.0233)	0.1000 (0.008)	0.0680 (0.010)	0.0900 (0.004)	0.0723 (0.007)

\* Expressed in milligrams per liter (standard error in parentheses).

Table 28

Steady-State Heavy Metal Sediment Concentrations\*  
in Anaerobic Oakland (Lower) Harbor Sediment

<u>Metal</u>	<u>Cycle Number</u>					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
As	5.39 (0.0007)	5.36 (0.004)	5.27 (0.014)	5.18 (0.018)	5.11 (0.021)	4.93 (0.002)
Cd	0.3689 (0.0002)	0.3674 (0.0004)	0.3624 (0.0001)	0.3596 (0.0002)	0.3573 (0.0004)	0.3547 (0.0008)
Cr	585.79 (0.0003)	585.66 (0.029)	584.72 (0.034)	584.40 (0.076)	584.21 (0.076)	583.85 (0.147)
Cu	40.79 (0.001)	40.68 (0.013)	40.20 (0.007)	39.98 (0.033)	39.84 (0.031)	39.65 (0.054)
Hg	0.5359 (0.00001)	0.5354 (0.0003)	0.5352 (0.0004)	0.5349 (0.0003)	0.5348 (0.0003)	0.5346 (0.0003)
Zn	78.34 (0.056)	78.15 (0.069)	77.45 (0.022)	77.06 (0.072)	76.34 (0.072)	76.49 (0.014)
						76.26 (0.202)

86

\* Expressed in micrograms per gram (standard error in parentheses).

Table 29

Heavy Metal Concentrations\* in Leachate from Anaerobic  
Oakland (Lower) Harbor Sediment

<u>Metal</u>	<u>Cycle Number</u>						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
As	0.0018 (0.0002)	0.0084 (0.001)	0.0220 (0.003)	0.0223 (0.0009)	0.0193 (0.002)	0.0193 (0.006)	0.0094 (0.008)
Cd	0.00029 (0.00006)	0.00039 (0.00005)	0.0012 (0.00008)	0.0007 (0.00004)	0.00058 (0.00006)	0.00065 (0.0002)	0.00050 (0.0002)
Cr	0.0020 (0.00008)	0.0330 (0.007)	0.2340 (0.005)	0.0800 (0.012)	0.0495 (0.006)	0.0899 (0.035)	0.0261 (0.007)
Cu	0.0022 (0.0003)	0.0285 (0.003)	0.1186 (0.005)	0.0567 (0.009)	0.0349 (0.002)	0.0458 (0.009)	0.0217 (0.004)
Hg	0.000024 (0.000003)	0.00012 (0.00006)	0.000058 (0.00003)	0.000070 (0.00002)	0.000030 (0.00001)	0.000039 (0.000008)	0.000025 (0.000009)
Zn	0.0390 (0.014)	0.0477 (0.012)	0.1767 (0.017)	0.0977 (0.013)	0.0553 (0.004)	0.0870 (0.027)	0.0577 (0.017)

\* Expressed in milligrams per liter (standard error in parentheses).

Table 30

Steady-State Heavy Metal Sediment Concentrations\*  
in Aerobic Oakland (Upper) Harbor Sediment

<u>Metal</u>	<u>Cycle Number</u>					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
As	10.19 (0.0007)	10.18 (0.0009)	10.11 (0.013)	10.00 (0.030)	9.89 (0.057)	9.81 (0.077)
Cd	0.9564 (0.0007)	0.9556 (0.0006)	0.9529 (0.0002)	0.9512 (0.0003)	0.9480 (0.0002)	0.9461 (0.0001)
Cr	321.30 (0.0003)	321.29 (0.002)	320.99 (0.108)	320.85 (0.088)	320.54 (0.082)	320.39 (0.099)
Cu	102.45 (0.002)	102.34 (0.006)	101.77 (0.084)	101.40 (0.071)	100.89 (0.071)	100.59 (0.095)
Hg	1.0119 (0.000007)	1.0119 (0.000006)	1.0119 (0.00001)	1.0118 (0.00002)	1.0118 (0.00002)	1.0118 (0.00002)
Zn	218.185 (0.029)	218.109 (0.025)	217.509 (0.160)	217.153 (0.130)	216.500 (0.109)	216.109 (0.151)
						215.771 (0.239)

\* Expressed in micrograms per gram (standard error in parentheses).



Table 31  
Heavy Metal Concentrations\* in Leachate from Aerobic  
Oakland (Upper) Harbor Sediment

Metal	Cycle Number						
	1	2	3	4	5	6	7
As	0.0016 (0.0002)	0.0046 (0.0004)	0.0173 (0.003)	0.0263 (0.004)	0.0277 (0.007)	0.0200 (0.005)	0.0138 (0.005)
Cd	0.00089 (0.0002)	0.0002 (0.00004)	0.00067 (0.0002)	0.00045 (0.00003)	0.00080 (0.00005)	0.00046 (0.00004)	0.00048 (0.0001)
Cr	0.0012 (0.00008)	0.0024 (0.0004)	0.0737 (0.027)	0.0352 (0.006)	0.0788 (0.003)	0.0368 (0.005)	0.0356 (0.015)
Cu	0.0118 (0.0005)	0.0279 (0.001)	0.1426 (0.022)	0.0932 (0.005)	0.1268 (0.005)	0.0749 (0.007)	0.0668 (0.013)
Hg	0.000016 (0.000002)	0.000008 (0.0000007)	0.000006 (0.000001)	0.000016 (0.000003)	0.000005 (0.0000009)	0.000001 (0.0000003)	0.000009 (0.0000005)
Zn	0.0287 (0.007)	0.0190 (0.001)	0.1500 (0.046)	0.0890 (0.008)	0.1633 (0.007)	0.0977 (0.011)	0.0847 (0.024)

\* Expressed in milligrams per liter (standard error in parentheses).

Table 32

Steady-State Heavy Metal Sediment Concentrations\*  
in Aerobic Oakland (Lower) Harbor Sediment

<u>Metal</u>	<u>Cycle Number</u>						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
As	5.40 (0.000)	5.40 (0.000)	5.378 (0.003)	5.340 (0.004)	5.282 (0.010)	5.236 (0.010)	5.202 (0.013)
Cd	0.3601 (0.0001)	0.3581 (0.0004)	0.3555 (0.0004)	0.3517 (0.0004)	0.3497 (0.0004)	0.3486 (0.0005)	0.3472 (0.0005)
Cr	585.80 (0.0001)	585.74 (0.019)	585.14 (0.043)	584.45 (0.033)	584.30 (0.099)	584.14 (0.098)	583.97 (0.097)
Cu	40.77 (0.002)	40.70 (0.020)	40.41 (0.021)	40.01 (0.019)	39.84 (0.008)	39.71 (0.006)	39.59 (0.005)
Hg	0.5360 (0.000002)	0.5360 (0.000003)	0.5359 (0.000007)	0.5359 (0.000001)	0.5358 (0.000004)	0.5358 (0.000004)	0.5358 (0.000004)
Zn	78.22 (0.000)	78.07 (0.039)	77.44 (0.037)	76.65 (0.044)	76.38 (0.028)	76.16 (0.028)	75.94 (0.034)

\* Expressed in micrograms per gram (standard error in parentheses).

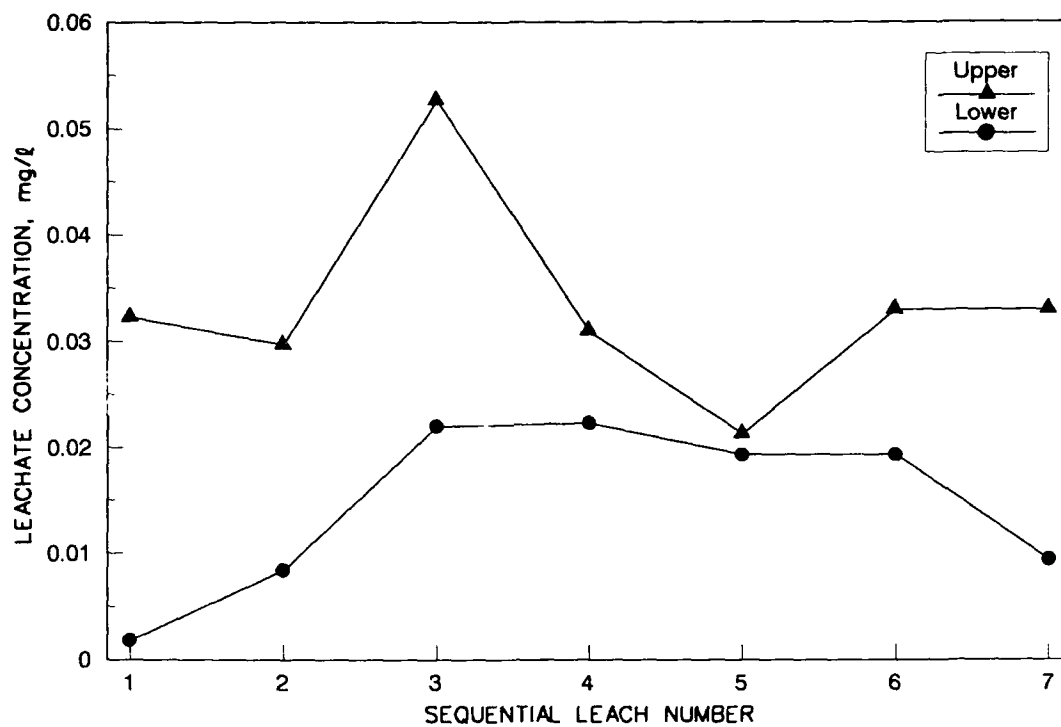
Table 33

Heavy Metal Concentrations\* in Leachate from Aerobic  
Oakland (Lower) Harbor Sediment

<u>Metal</u>	<u>Cycle Number</u>						
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>	<u>7</u>
As	<0.00095	<0.00095	0.0056 (0.0008)	0.0095 (0.0002)	0.0143 (0.003)	0.0117 (0.0003)	0.0085 (0.0007)
Cd	0.00247 (0.00004)	0.00051 (0.0001)	0.00064 (0.00001)	0.00096 (0.00008)	0.00048 (0.00006)	0.00029 (0.00003)	0.00033 (0.00002)
Cr	0.0009 (0.00003)	0.0145 (0.005)	0.1508 (0.008)	0.1719 (0.003)	0.0360 (0.018)	0.0421 (0.003)	0.0426 (0.001)
Cu	0.0068 (0.0006)	0.0174 (0.005)	0.0737 (0.003)	0.0997 (0.002)	0.0412 (0.003)	0.0327 (0.0008)	0.0320 (0.0006)
Hg	0.0000042 (0.0000004)	0.0000067 (0.0000008)	0.0000075 (0.000001)	0.000011 (0.000002)	0.0000088 (0.0000008)	0.000011 (0.000002)	0.000010 (0.000002)
Zn	0.0700 (0.000)	0.0387 (0.010)	0.1567 (0.004)	0.1963 (0.003)	0.0690 (0.005)	0.0533 (0.002)	0.0557 (0.001)

\* Expressed in milligrams per liter (standard error in parentheses).

### ANAEROBIC



### AEROBIC

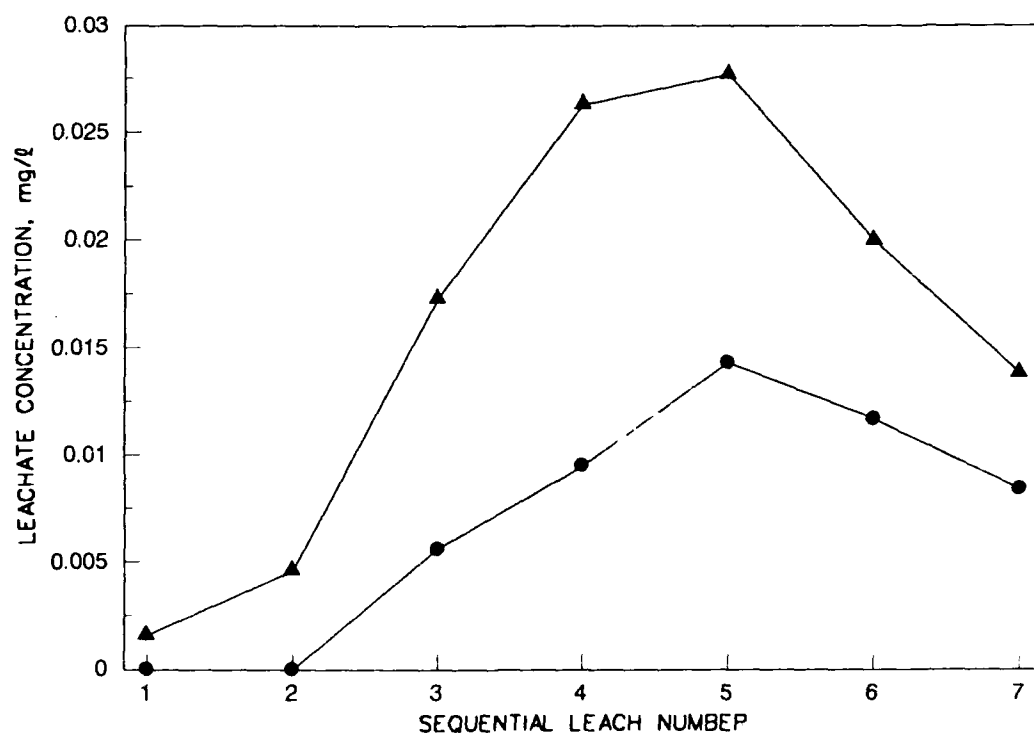
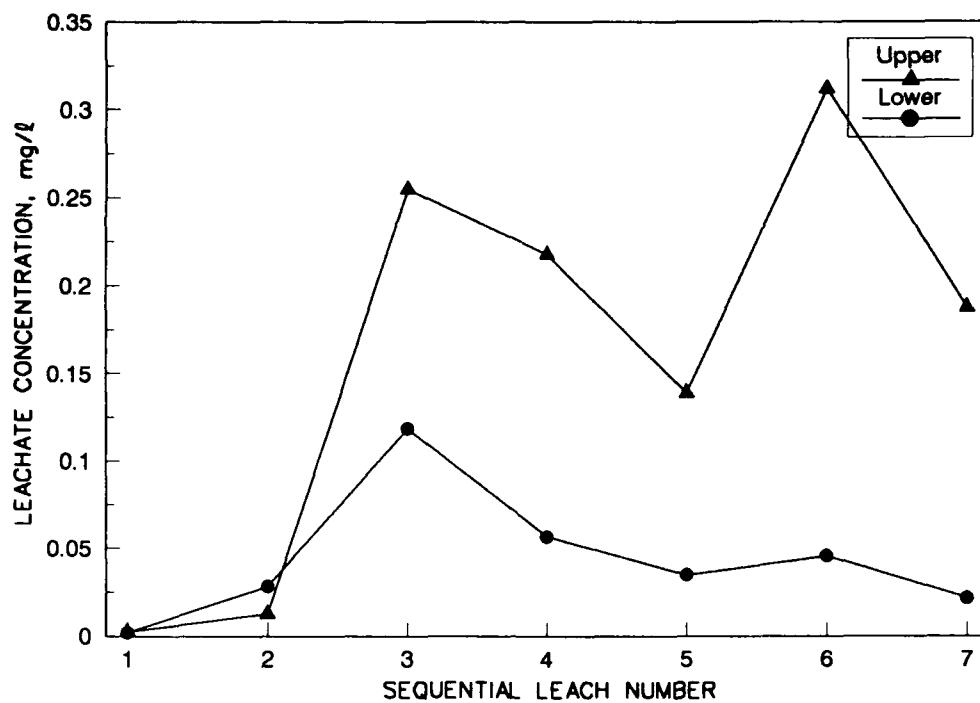


Figure 27. Arsenic concentrations in Oakland floor sequential batch leachate

### ANAEROBIC



### AEROBIC

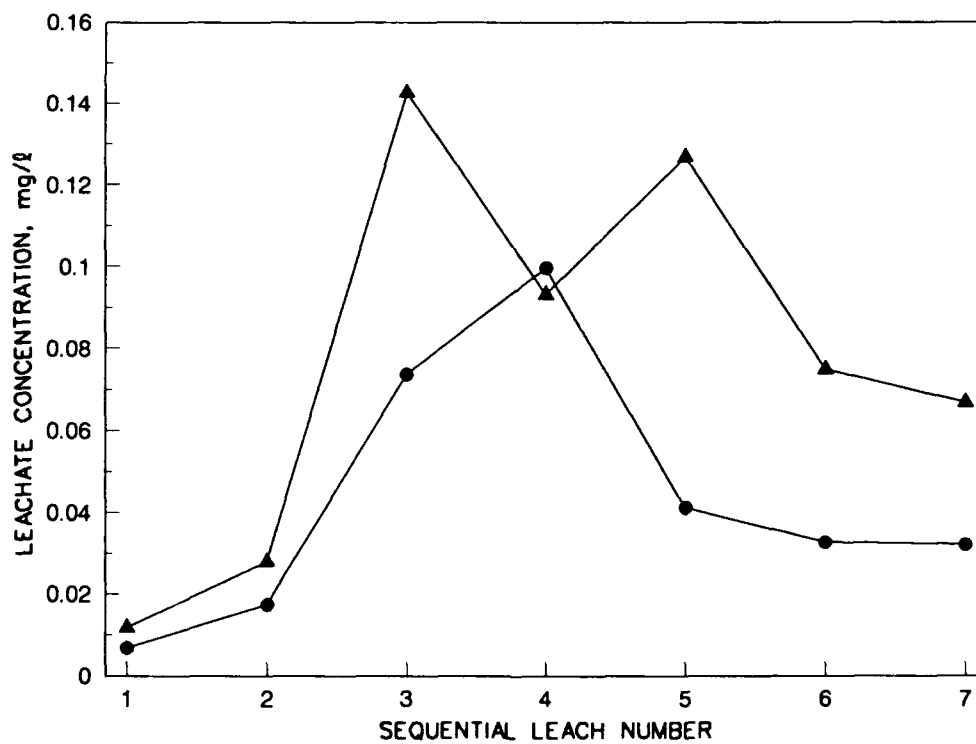


Figure 28. Copper concentrations in Oakland Harbor sequential batch leachate

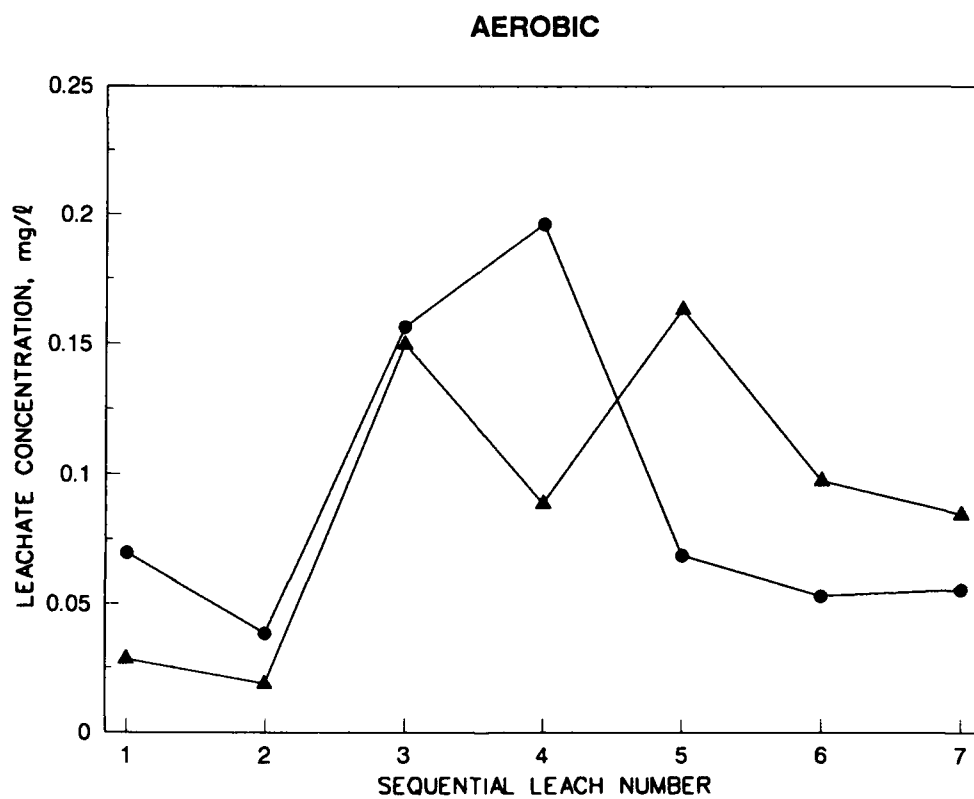
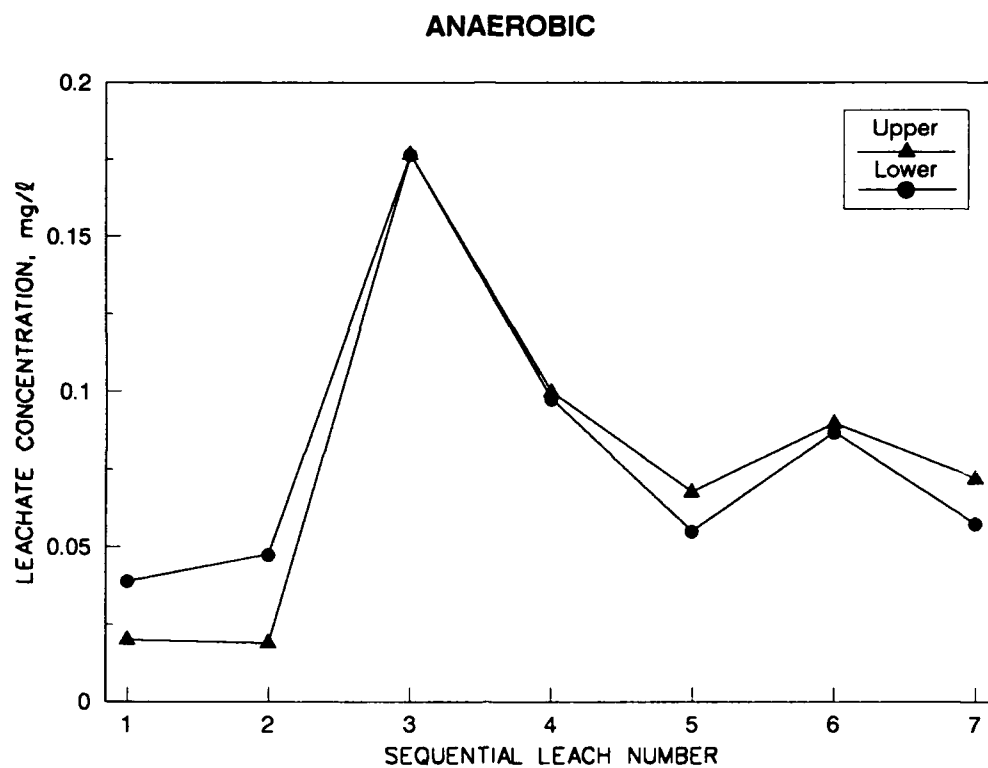


Figure 29. Zinc concentrations in Oakland Harbor sequential batch leachate

greater number of replicate analyses and the resulting higher reliability of the data.

Steady-state butyltin concentrations in sediment and leachate obtained from the sequential batch leaching tests for anaerobic Oakland Harbor upper sediment are presented in Table 34. Tributyltin and monobutyltin concentrations remained substantially unchanged during sequential leaching. Dibutyltin concentrations, however, were elevated in the third and fourth leach cycles.

Steady-state butyltin concentrations in sediment and leachate obtained from the sequential batch leaching tests for anaerobic Oakland Harbor lower sediment are presented in Table 35. Tributyltin and monobutyltin concentrations remained substantially unchanged during sequential leaching. However, dibutyltin concentrations were elevated in the second leach cycle.

Butyltin compound concentrations in sediment and leachate obtained from the sequential batch leaching tests for aerobic Oakland Harbor upper sediment are presented in Table 36. Tributyltin leachate concentrations peaked at the third leach cycle. Dibutyltin and monobutyltin leachate concentrations were statistically higher in the third and fourth leach cycles compared to leachate concentrations in the remaining leach cycles.

Steady-state organotin concentrations in sediment and leachate obtained from the sequential batch leaching tests for aerobic Oakland Harbor lower sediment are presented in Table 37. Tributyltin and dibutyltin leachate concentrations did not change statistically ( $P < 0.05$ ) during the entire sequential leaching cycle. Monobutyltin leachate concentrations were statistically ( $P < 0.05$ ) higher in the second through fourth leach cycles compared to the remaining cycles.

Leachate concentrations of tributyltin during sequential batch leaching of anaerobic and aerobic Oakland Harbor sediments are illustrated in Figure 30. The peaks in leachate concentration following the first two leach cycles are evident for this compound.

Interstitial water metal and organotin concentrations. Metal and organotin concentrations in the interstitial water of anaerobic Oakland Harbor sediment are presented in Table 38. Concentrations of most constituents in Oakland Harbor upper sediments were comparable to concentrations in lower sediments. This was true in spite of differences in total sediment constituent concentrations and differences in the physical properties of the sediments.

Table 34

Steady-State Butyltin Sediment\* and Leachate\*\* Concentrations  
in Anaerobic Oakland (Upper) Harbor Sediment

<u>Parameter</u>	<u>Sediment - Cycle Number</u>					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
Tributyltin	701.40 (0.014)	701.23 (0.050)	699.69 (0.100)	698.23 (0.960)	697.66 (1.32)	697.23 (1.49)
Dibutyltin	153.45 (0.009)	153.35 (0.011)	152.93 (0.076)	152.42 (0.120)	152.06 (0.224)	151.84 (0.326)
Monobutyltin	18.49 (0.012)	18.47 (0.011)	18.33 (0.117)	18.25 (0.109)	18.17 (0.094)	18.11 (0.095)

	<u>Leachate - Cycle Number</u>					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
Tributyltin	0.0240 (0.004)	0.0433 (0.009)	0.3847 (0.036)	0.3643 (0.262)	0.1443 (0.089)	0.1067 (0.045)
Dibutyltin	0.0121 (0.002)	0.0243 (0.0007)	0.1063 (0.020)	0.1283 (0.042)	0.0883 (0.031)	0.0567 (0.025)
Monobutyltin	0.0031 (0.003)	0.0036 (0.0007)	0.0361 (0.027)	0.0203 (0.006)	0.0184 (0.007)	0.0167 (0.004)

\* Expressed in micrograms per kilogram (standard error in parentheses).

\*\* Expressed in micrograms per liter (standard error in parentheses).



Table 35

Steady-State Butyltin Sediment\* and Leachate\*\* Concentrations  
in Anaerobic Oakland (Lower) Harbor Sediment

<u>Parameter</u>	<u>Sediment - Cycle Number</u>					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
Tributyltin	35.33 (0.007)	35.24 (0.008)	35.12 (0.005)	34.99 (0.011)	34.88 (0.004)	34.78 (0.018)
Dibutyltin	7.310 (0.011)	7.252 (0.018)	7.171 (0.022)	7.097 (0.019)	7.006 (0.021)	6.924 (0.019)
Monobutyltin	1.827 (0.006)	1.796 (0.015)	1.762 (0.015)	1.711 (0.019)	1.673 (0.017)	1.629 (0.005)
	<u>Leachate - Cycle Number</u>					
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
Tributyltin	0.0153 (0.002)	0.0200 (0.003)	0.0287 (0.003)	0.0327 (0.003)	0.0287 (0.004)	0.0237 (0.004)
Dibutyltin	0.0100 (0.003)	0.0143 (0.002)	0.0203 (0.002)	0.0187 (0.003)	0.0230 (0.0006)	0.0200 (0.010)
Monobutyltin	0.0057 (0.001)	0.0078 (0.003)	0.0085 (0.004)	0.0127 (0.004)	0.0096 (0.001)	0.0100 (0.005)

\* Expressed in micrograms per kilogram (standard error in parentheses).

\*\* Expressed in micrograms per liter (standard error in parentheses).

Table 36

Steady-State Butyltin Sediment\* and Leachate\*\* Concentrations  
in Aerobic Oakland (Upper) Harbor Sediment

<u>Parameter</u>	<u>Sediment - Cycle Number</u>				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Tributyltin	701.39 (0.001)	701.26 (0.062)	697.20 (1.00)	695.94 (1.03)	695.19 (1.02)
Dibutyltin	153.47 (0.017)	153.37 (0.049)	152.67 (0.355)	151.87 (0.361)	151.67 (0.336)
Monobutyltin	18.45 (0.006)	18.37 (0.025)	17.59 (0.362)	17.47 (0.349)	17.23 (0.307)
	<u>Leachate - Cycle Number</u>				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Tributyltin	0.0273 (0.0003)	0.0325 (0.016)	1.015 (0.263)	0.3153 (0.014)	0.1883 (0.006)
Dibutyltin	0.0086 (0.004)	0.0231 (0.014)	0.1750 (0.077)	0.1997 (0.044)	0.0513 (0.009)
Monobutyltin	0.0121 (0.002)	0.0195 (0.007)	0.1963 (0.086)	0.0300 (0.005)	0.0600 (0.016)

\* Expressed in micrograms per kilogram (standard error in parentheses).

\*\* Expressed in micrograms per liter (standard error in parentheses).

Table 37

Steady-State Butyltin Sediment\* and Leachate\*\* Concentrations  
in Aerobic Oakland (Lower) Harbor Sediment

<u>Parameter</u>	<u>Sediment - Cycle Number</u>				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Tributyltin	35.31 (0.019)	35.25 (0.024)	35.16 (0.059)	35.00 (0.118)	34.95 (0.125)
Dibutyltin	7.289 (0.019)	7.256 (0.028)	7.197 (0.044)	7.112 (0.073)	7.068 (0.073)
Monobutyltin	1.840 (0.010)	1.800 (0.013)	1.779 (0.008)	1.760 (0.008)	1.749 (0.010)
	<u>Leachate - Cycle Number</u>				
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>
Tributyltin	0.0173 (0.005)	0.0143 (0.002)	0.0237 (0.009)	0.0387 (0.015)	0.0147 (0.002)
Dibutyltin	0.0152 (0.005)	0.0083 (0.002)	0.0147 (0.004)	0.0213 (0.007)	0.0110 (0.003)
Monobutyltin	0.0025 (0.003)	0.0099 (0.001)	0.0052 (0.001)	0.0048 (0.0005)	0.0029 (0.001)

\* Expressed in micrograms per kilogram (standard error in parentheses).

\*\* Expressed in micrograms per liter (standard error in parentheses).

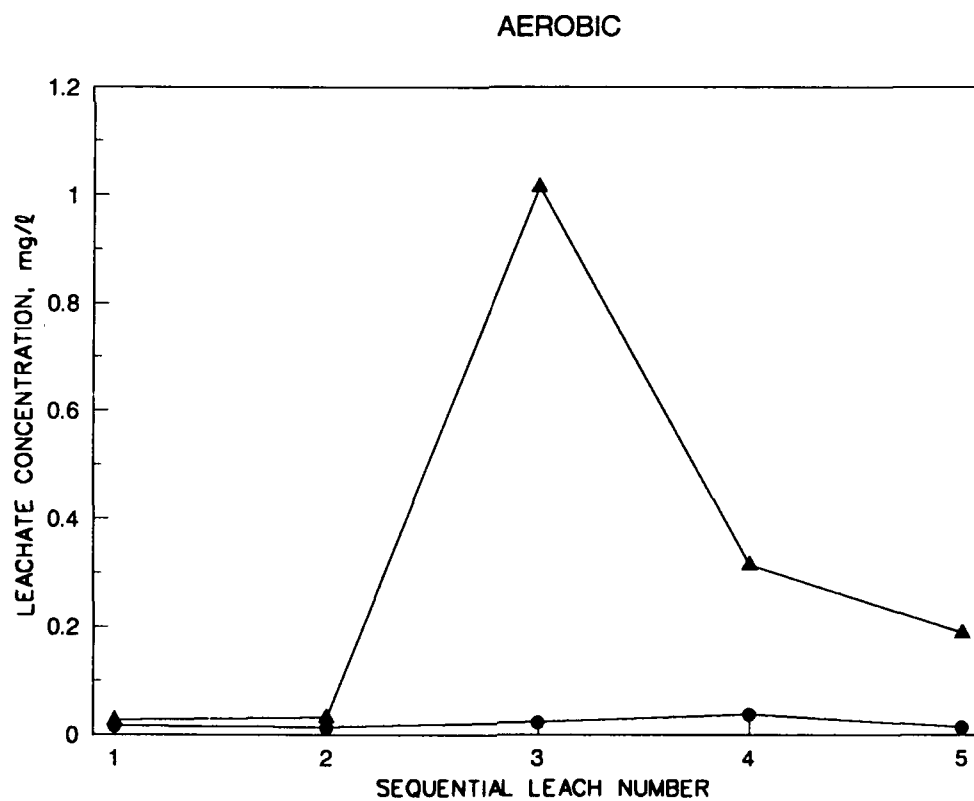
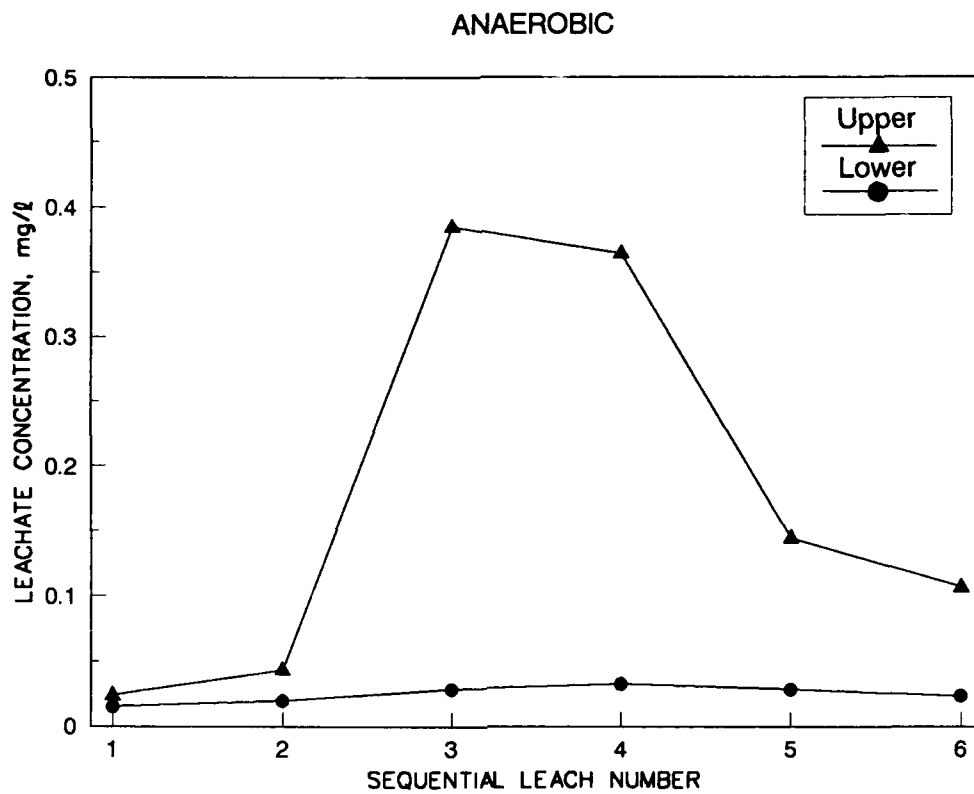


Figure 30. Tributyltin concentrations in Oakland Harbor sequential batch leachate

Table 38  
Interstitial Water Metal [ $\mu\text{g}/\ell$  (Standard Error)] and Organotin  
Compound [ $\text{ng}/\ell$  (Standard Error)] Concentrations  
in Anaerobic Oakland Harbor Sediment

<u>Parameter</u>	<u>Upper</u>		<u>Lower</u>	
As	43	(0.4)	44	(4.0)
Cd	0.2	(0.1)	0.26	(0.01)
Cr	2.0	(0.07)	1.6	(1.0)
Cu	46	(6.0)	50	(7.0)
Hg	0.08	(0.03)	0.2	(0.04)
Zn	24	(4.0)	58	(9.0)
Tributyltin	16	(1.5)	12	(2.0)
Dibutyltin	7	(2.3)	6	(1.6)
Monobutyltin	4	(4.0)	3	(1.7)

Cumulative and percentage losses of metals and butyltin during leaching.

Cumulative net mass releases of metals from Oakland Harbor upper and lower sediment were generally similar between sediments, except for Cu, which showed substantially more release from Oakland Harbor upper sediment (Table 39). Cumulative net mass releases following leaching of aerobic sediment were either similar to or lower than releases from anaerobic sediment. Percents of metals and organotin compounds lost were lower in leachate from aerobic than from anaerobic sediments (Table 40). This is consistent with the lack of pH drop during sediment oxidation and is probably due to fixation of metals in iron oxides during oxidation.

Discussion

Distribution coefficients could not be calculated because sequential batch leaching of both anaerobic and aerobic Oakland Harbor sediment did not follow classical desorption theory. The appearance of peaks in the leachate concentration data indicated nonconstant sediment geochemistry and nonconstant distribution coefficients during leaching. If constant distribution coefficients existed, contaminant concentrations would not have exceeded initial values. The changes in sediment geochemistry are reflected in the changes in

Table 39

Cumulative Mass Loss ( $\mu\text{g/g}$ ) of Metals and Organotin Compounds from Oakland  
Harbor Sediments Following Seven Cycles of Leaching for Metals  
and Five Cycles of Leaching for Organotin Compounds

<u>Parameter</u>	<u>Oakland Upper</u>		<u>Oakland Lower</u>	
	<u>Anaerobic</u>	<u>Aerobic</u>	<u>Anaerobic</u>	<u>Aerobic</u>
As	0.93	0.44	0.41	0.20
Cd	0.02	0.02	0.02	0.02
Cr	1.57	1.06	2.06	1.84
Cu	4.51	2.18	1.23	1.21
Hg	0.0004	0.0003	0.001	0.0002
Zn	2.18	2.53	2.24	2.56
Tributyltin	0.0042	0.0063	0.0005	0.0004
Dibutyltin	0.0017	0.0018	0.0004	0.0003
Monobutyltin	0.0004	0.0013	0.0002	0.0001

Table 40

Percent Mass Loss of Heavy Metals from Oakland Harbor Sediment  
Under Anaerobic and Aerobic Conditions Following Seven  
Sequential Batch Leach Cycles

<u>Parameter</u>	<u>Oakland Upper</u>		<u>Oakland Lower</u>	
	<u>Anaerobic</u>	<u>Aerobic</u>	<u>Anaerobic</u>	<u>Aerobic</u>
As	9.14	4.36	6.97	3.36
Cd	2.08	1.65	4.68	6.16
Cr	0.49	0.33	0.35	0.31
Cu	4.40	2.12	3.02	2.98
Hg	0.035	0.025	0.027	0.045
Zn	1.00	1.16	2.94	3.26
Tributyltin	1.49	2.20	3.46	2.99
Dibutyltin	2.13	2.34	8.13	7.52
Monobutyltin	3.14	10.2	14.2	8.09

conductivity and pH during sequential leaching. As discussed in Myers and Brannon (1988), several approaches to modeling the source term (distribution coefficient) have been proposed and evaluated. These models were formulated to describe the distribution of contaminant concentrations versus time for brief episodes of contaminant input to a clean soil or sediment column. During the desorption phase, the models simulate leaching of contaminated solids with clean water. Because constant partitioning is assumed by these models, the models predict contaminant elution from contaminated soils or sediment to follow the form of a classical elution curve; that is, contaminant concentrations monotonically decrease. These models are therefore not applicable to leaching of Oakland Harbor sediment with DDI water. Alternative, simplified procedures based on leachate data will be used to estimate contaminant mass losses via leaching. This will be discussed in greater detail in the following section (Leachate Impacts and Controls).

Analyses for PAHs were not conducted in this study because the PAHs occurred in relatively low concentrations in Oakland Harbor sediments and are rapidly lost through degradation and volatilization following disposal of dredged material. Previous work has shown that up to 86 percent of sediment PAH can be lost during sediment oxidation (Environmental Laboratory 1987) and that subsequent concentrations of PAH in leachate are generally below analytical detection limits (Environmental Laboratory 1987, Myers and Brannon 1988).

Oakland Harbor sediment did not exhibit the pronounced drop in pH following oxidation observed for other marine sediments (Environmental Laboratory 1987, Myers and Brannon 1988) or for an Oakland Inner Harbor surface sediment grab sample used in a previous study (Brannon, Plumb, and Smith 1978). The present study used composited core samples that are different in physical and chemical characteristics from the grab samples and are more representative of the material to be dredged.

The oxidation of Oakland Harbor sediment did not result in increased leaching of metals compared to anaerobic sediment. In fact, leaching of many metals following sediment oxidation was reduced compared to leaching under anaerobic conditions (Table 40). From a management perspective, these results indicated that no precautions need be taken to prevent sediment oxidation of Oakland Harbor dredged material.

Anaerobic leachate results of first-day kinetics and the first sequential leach cycle for upper sediments were comparable to respective interstitial water concentrations except that Cu concentrations were higher in the

interstitial water. For anaerobic leachate evaluations it was therefore decided to use interstitial water metal and organotin concentrations. For aerobic leachate evaluations, the first sequential batch leachate data are appropriate, as was the case for New Bedford Harbor leaching data (Myers and Brannon 1988).

The highest value achieved in the first step of the aerobic or anaerobic leachate or in the interstitial water was used in making calculations in the following section of this report. Only highest values were used because of the similarity of aerobic and anaerobic leachate results and the extended times needed for water to percolate through the material.

### Leachate Impacts and Controls

#### Discussion

Leachate from dredged material placed in a disposal site is produced by three potential sources: (a) the original pore water, or interstitial water from the dredged material, (b) net movement of precipitation through the dredged material, and (c) for nearshore sites, groundwater or estuary water contacting the dredged material as a result of tidal pumping. The levee alternative being considered for Oakland will be affected by the first two sources. A confined disposal facility adjoining a waterway may be affected by tidal pumping if the CDF walls are permeable. For this analysis, the assumption was made that CDFs will be sited in an upland location where tidal pumping is not a factor. The effects of an adjoining water body on potential leachate impacts are discussed only for the Twitchell Island levee disposal scenario.

The rate of leachate movement through the dredged material is primarily a function of hydraulic conductivity as measured by permeability tests. Permeabilities for the two Oakland sediments are illustrated as a function of void ratio in Figures 31 and 32. Permeabilities for the upper sediment ranged from  $0.35\text{E-}07$  to  $5.8\text{E-}07$  cm/sec and, for the lower sediment, from  $0.83\text{E-}05$  to  $1.27\text{E-}05$  cm/sec. Lower void ratios, which represent lower water contents, produce lower permeabilities. Dredged material placed in a disposal site will consolidate, releasing water and developing lower void ratios with time. Once the dredged material begins drying at the surface as a result of evapotranspiration, the material becomes unsaturated, generally resulting in reduced hydraulic conductivities compared to saturated material.



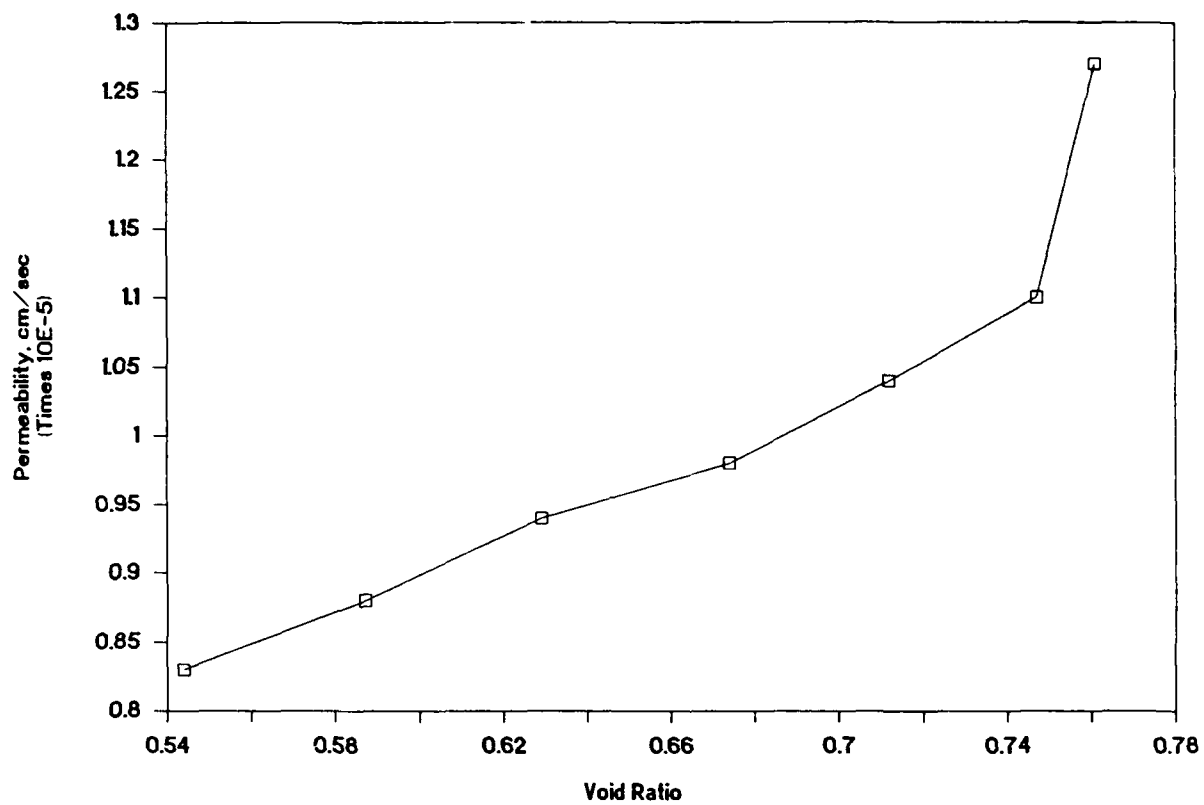


Figure 31. Falling head permeability data for Oakland Harbor (upper)

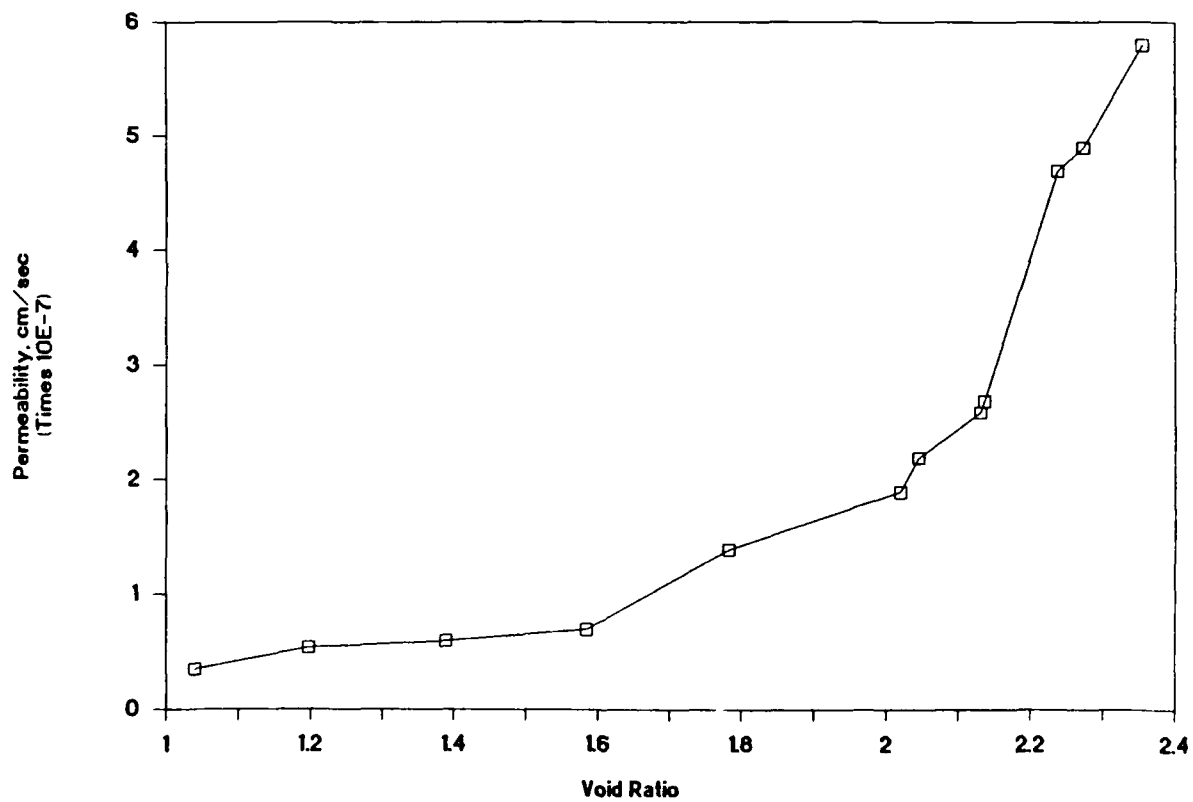


Figure 32. Falling head permeability data for Oakland Harbor (lower)

The maximum quantity of seepage through a layer of dredged material can be estimated by assuming that the material remains saturated and moves only in the downward direction (perpendicular to the surface) under laminar flow conditions. This estimate is obtained by applying Darcy's equation, which may be written as follows:

$$Q = kA \left( \frac{dH}{dL} \right)$$

where

Q = volumetric flow rate, cu ft/year

k = coefficient of permeability, ft/year

A = flow through surface area, sq ft

dH/dL = hydraulic gradient, ft/ft

In a disposal site where no additional head or free water exists above the surface of the dredged material, the hydraulic gradient is unity. Tables 41 and 42 show how three disposal alternative designs affect the rate of leachate movement through Oakland Harbor upper and lower dredged material samples. Seepage rates were calculated using the above equation for placed dredged material lifts of 1, 3, and 12 ft. The 1- and 3-ft lifts were selected to represent a range of designs that may be considered for placement of the material on a levee; the 12-ft lift represents a typical CDF. Obviously, the thicker the lift of dredged material, the smaller the surface area of the disposal site and the smaller the volume of seepage.

The purpose of these tables is to present a worst-case (shortest) time frame that may be represented by the batch leaching tests. For Oakland Harbor upper sediment, Table 41 shows that the time period ranges from 5 years for the first step of the test with a 1-ft lift to 393 years for the seventh step with a 12-ft CDF. For Oakland Harbor lower sediment, this range is much shorter: 0.03 to 38 years. The reduced initial water content of the lower sediment sample, which yields a greater weight of dry solids, together with the increased permeability of the sediment, is responsible for the faster rates of seepage flow for the lower sample. This is a simplified analysis that assumes that the dredged material remains saturated, which will be the case only immediately after placement and after extended rainfall or irrigation. Rainfall in the Oakland area averages about 19 in. per year. Averaging

Table 41

Evaluation of Leachate Movement through Oakland Upper Sediment

Parameter	Depth of Placement at Disposal Site		
	1 ft	3 ft	12 ft
Volume sediment placed, cu yd	100,000	100,000	100,000
Initial sediment water content, percent	105.9	105.9	105.9
Specific gravity of solids	2.73	2.73	2.73
Permeability, cm/sec	5.8E-07	5.8E-07	5.8E-07
Weight dry sediment solids, lb	1.2E+08		
Weight interstitial water, lb	1.3E+08		
Surface area of disposal site, sq ft	2.7E+06	9.0E+05	2.3E+05
No. years to produce seepage volume equal to			
1 interstitial water volume	1	4	15
1 batch leaching step volume	5	14	56
5 batch leaching step volumes	23	70	281
7 batch leaching step volumes	33	98	393

this rainfall amount over the entire year yields an equivalent rate of 1.5E-06 cm/sec. This rate is greater than the permeability of the upper sediment, but less than the permeability of the lower sediment by a factor of 8. Therefore, the number of years shown in Table 42 for the lower sample should be multiplied by 8, if the only source of water is direct rainfall on the surface.

To more realistically estimate the seepage for Oakland Harbor sediment in a disposal site, the Hydrologic Evaluation of Landfill Performance (HELP) model was applied. HELP was designed to model water movement across, into, through, and out of landfills. The model accepts climatological, soil, and design data and accounts for surface storage, runoff, winter cover, infiltration, percolation, evapotranspiration, and soil moisture storage. The result is a water balance that includes the volume of runoff and percolation through the base of the site. Five alternative scenarios were selected to demonstrate use of the HELP model for estimation of percolation rates and to compare control measures for a CDF. Scenarios A through D are CDF alternatives for a CDF with 12-ft depth. Scenario E is for placement of the dredged material on a levee in a 3-ft lift.

Table 42

Evaluation of Leachate Movement through Oakland Lower Sediment

Parameter	Depth of Placement at Disposal Site		
	1 ft	3 ft	12 ft
Volume sediment placed, cu yd	400,000	400,000	400,000
Initial sediment water content, percent	30.6	30.6	30.6
Specific gravity of solids	2.73	2.73	2.73
Permeability, cm/sec*	1.3E-05	1.3E-05	1.3E-05
Weight dry sediment solids, lb	1.0E+09	1.0E+09	1.0E+09
Weight interstitial water, lb	3.1E+08	3.1E+08	3.1E+08
Surface area of disposal site, sq ft	1.1E+07	3.6E+06	9.0E+05
No. years to produce seepage volume equal to			
1 interstitial water volume	0.03	0.1	0.4
1 batch leaching step volume	0.5	1	5
5 batch leaching step volumes	2	7	27
7 batch leaching step volumes	3	10	38

\* Permeability for lower sediment is 161 in./year, which exceeds normal rainfall of 19 in./year.

The alternatives are described as follows:

- a. Scenarios A1 and A2. Disposal of the upper and lower sediments is in separate CDFs, A1 and A2, respectively. This includes no controls, other than routine management of the CDF surface to provide for drainage of surface runoff. For comparison of this alternative to other alternatives that combine the upper and lower sediment in a single CDF, volumes from A1 and A2 are added.
- b. Scenario B. Disposal of the upper sediment is in the bottom of the CDF, and the lower sediment is on top of the upper sediment. This provides the advantage of a less permeable material in the bottom of the CDF. However, this advantage is reduced by the increased infiltration of rainfall through more permeable surface material.
- c. Scenario C. The lower sediment is placed in the bottom of the CDF, with the upper sediment placed on top. This is an illogical sequence from an operational perspective, but it illustrates the benefits of a less permeable surface material. Dredged material with characteristics similar to the upper sediment could possibly be obtained from another site to provide an equivalent capping material.
- d. Scenario D. A leachate collection system and a geomembrane liner are used to control leachate percolating through the dredged material. The collected leachate would have to be treated to remove

contaminants with an onsite system or would have to be transported to an appropriate wastewater treatment facility.

- e. Scenario E1 + E2. Disposal of the dredged material is on a levee, such as is proposed for Twitchell Island (Figure 33). The upper and lower sediments would be disposed of independently in a 3-ft lift. HELP will overestimate percolation and underestimate runoff, because the effect of levee side slopes on the water budget is not considered.

HELP model runs for each of these scenarios used the same basic parameters. Climatic data were generated for a 10-year period by the model, based on historical climatic data for the San Francisco area. The sediment was assumed to be saturated at the water content for the permeability point representing the highest void ratios in Figures 31 and 32. A Soil Conservation Service runoff curve number of 88 was used. The surface of the CDF or levee was assumed to be devoid of vegetation. An example of the HELP-generated data is presented in Appendix D.

Figure 34 shows the annual percolation from the base of a CDF for the first 10 years of operation for scenarios A-D. HELP assumes that the bottom of the site is free-draining. If a barrier less permeable than the dredged material can be constructed for the bottom of the CDF, percolation rates can be reduced. The high rates during the early years are a result of drainage of the pore water that is associated with the material when initially placed in the site. By the tenth year, fluctuations appear to reach steady conditions with perturbations caused by varying climatic conditions. Scenarios A2 and B have higher percolation rates at 10 years because of the more permeable "lower" sediment on the surface of these CDFs. As expected, the lined alternative (D) has the lowest percolation rate, but the cost for implementation of these controls is significant. Figure 35 compares the cumulative percolation volumes from the alternative CDFs over the 10-year period. The tenth-year volumes show the order of scenarios as  $B > A > C > D$ .

HELP runs for Scenario E produced generally greater percolation volumes (Table 43) because of the increased surface area available for precipitation. The exception is for the upper material, whose lower permeability allowed for greater evapotranspiration after the first 10 years and a lower percolation volume compared to Scenario A1. In contrast, Scenario E2 produced the greatest percolation rates of any of the CDF alternatives.

Earlier discussion indicated that using Darcy's equation overestimated the volume of leachate for dredged material disposal. Table 43 compares the batch leaching test volumes to the percolation volumes estimated by the HELP

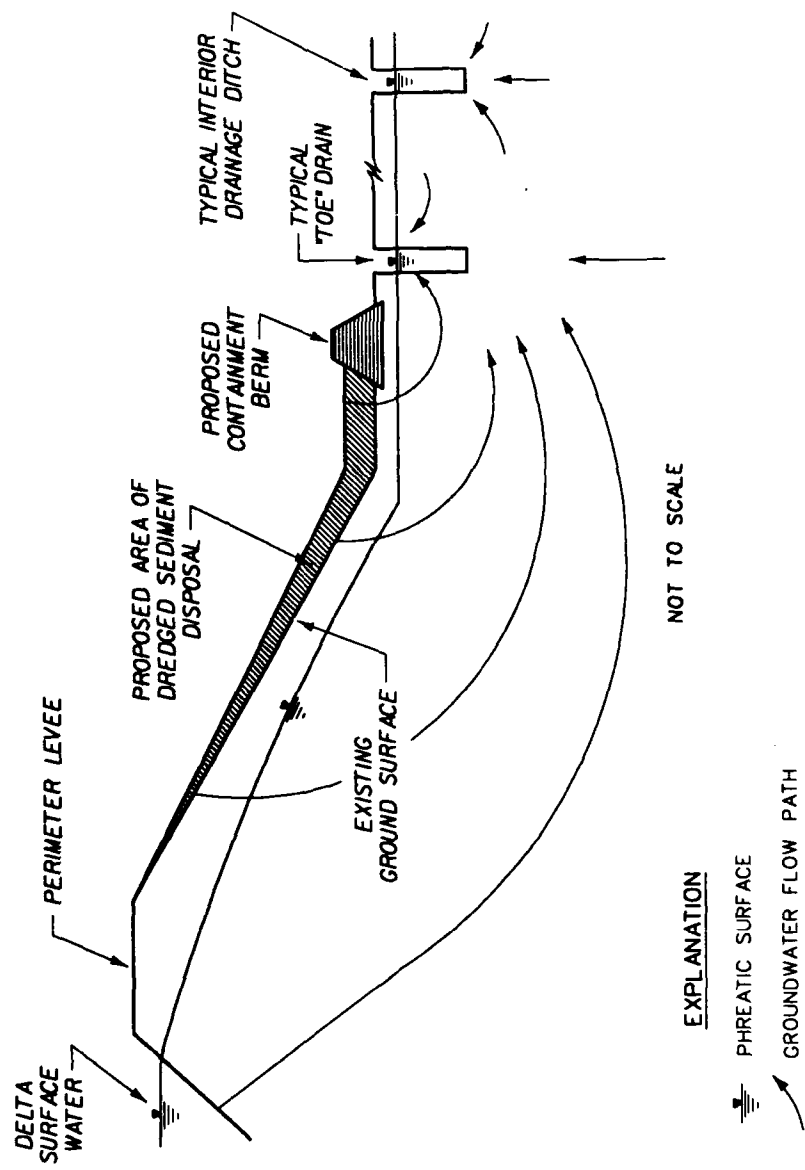


Figure 33. Typical cross section of levee and drainage system

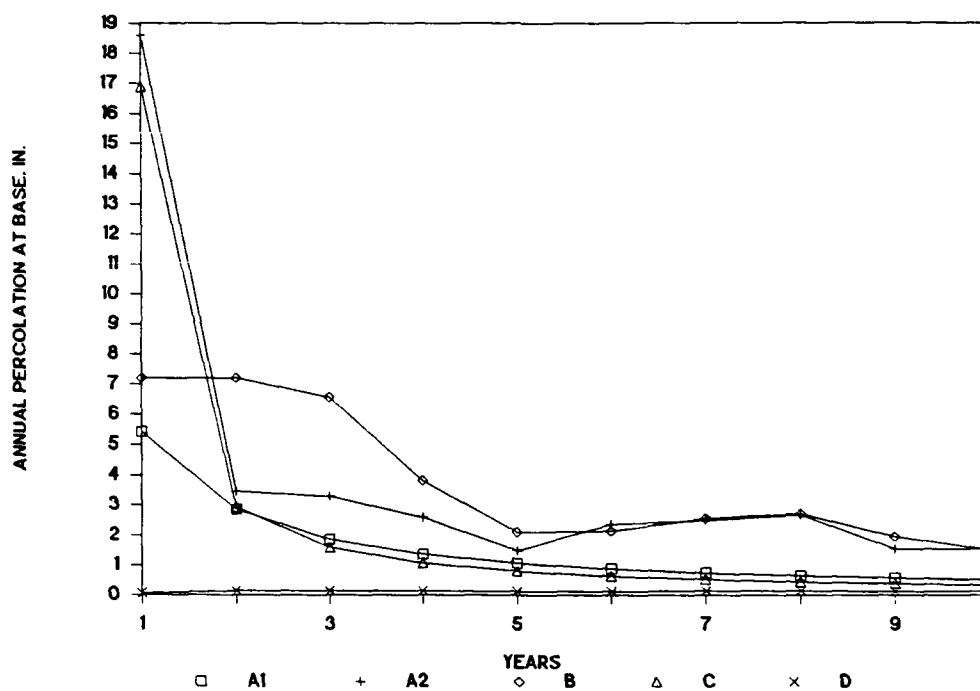


Figure 34. HELP model estimates of annual percolation rates for CDF alternatives

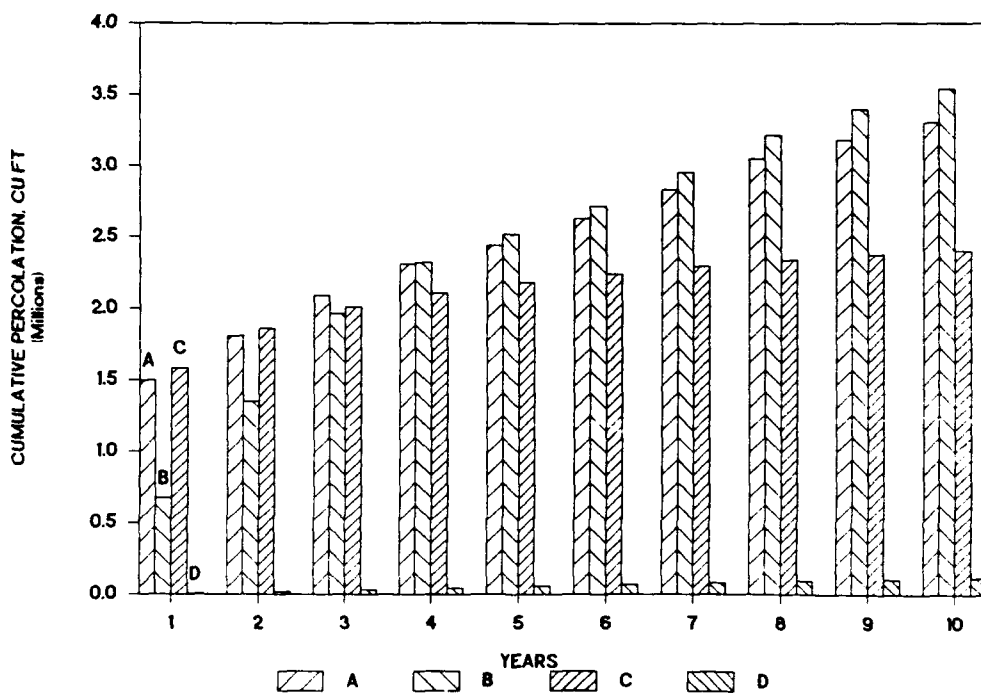


Figure 35. HELP model estimates of cumulative percolation volume for CDF alternatives

Table 43

Comparison of Percolation Volumes\* to Batch Leaching Test Volumes

<u>Scenario</u>	<u>Percolation Volume, Years 1-10 cu ft</u>	<u>Leaching Volume per Step cu ft</u>	<u>Percolation Volume, Years 1-10 Leach Steps</u>	<u>Annual Percolation Volume cu ft</u>	<u>Percolation Time for 1 Step** years</u>
<u>Confined Disposal Facility</u>					
A1	300,000	7,500,000	0.040	9,600	760
A2	3,000,000	64,000,000	0.047	120,000	540
A1 + A2	3,300,000	72,000,000	0.046	130,000	560
B	3,500,000	72,000,000	0.049	140,000	490
C	2,400,000	72,000,000	0.033	32,000	2,200
D	120,000	72,000,000	0.002	11,000	6,300
<u>Levee</u>					
E1	400,000	7,500,000	0.053	5,800	1,200
E2	7,100,000	64,000,000	0.11	390,000	160
E1 + E2	7,500,000	72,000,000	0.10	390,000	180

\* Based on HELP model.

\*\* Years 10-6,300 use percolation at year 10 from HELP model.

model. This table shows that the percolation volume from the HELP model is at least two orders of magnitude lower than the volume for one batch leaching step. The volume for the leaching step is based on the total mass of solids dredged. The annual percolation rate for the tenth year was assumed to continue at that rate for succeeding years in order to calculate the number of years of percolation equivalent to the leaching volume of the first step of the batch leaching test. This time period ranges from 160 to 6,300 years. Therefore, using the total mass of contaminant released by 5 to 7 steps of the batch leaching test is a very conservative projection of the loss of contaminants via leaching from Oakland Harbor sediments.

Assessment of  
leachate contaminant releases

As shown in Table 43, worst-case leachate movement through a 3-ft lift of Oakland Harbor dredged material will require many years to represent a single step of the batch leaching test. Therefore, leachate quality for the first step or for interstitial water initially contained in the sediment is appropriate for comparison to regulatory limits. Tables 44 and 45 compare



Table 44

Comparison of Leachate Concentrations ( $\mu\text{g}/\ell$ ) to Regulatory Limits  
for Oakland (Upper) Harbor Sediment

<u>Constituent</u>	<u>Inter- stitial Water</u>	<u>Step 1 Anaerobic Leachate</u>	<u>Step 1 Aerobic Leachate</u>	<u>Maximum Contaminant Level*</u>	<u>Effluent Limits</u>	<u>Receiving Water Limits</u>
Arsenic	43	32	1.6	50	50	1
Cadmium	0.20	0.30	0.89	10	1.8	0.65
Chromium	2.0	2.4	1.2	50	16	98
Copper	46	2.6	12		9.2	6.5
Mercury	0.080	0.0070	0.016	2	2.4	0.012
Zinc	24	20	29		65	59
Tributyltin	16	0.024	0.027		0.08	0.02

\* Level specified for compliance with Safe Drinking Water Act.

Table 45

Comparison of Leachate Concentrations ( $\mu\text{g}/\ell$ ) to Regulatory Limits  
for Oakland (Lower) Harbor Sediment

<u>Constituent</u>	<u>Inter- stitial Water</u>	<u>Step 1 Anaerobic Leachate</u>	<u>Step 1 Aerobic Leachate</u>	<u>Maximum Contaminant Level</u>	<u>Effluent Limits</u>	<u>Receiving Water Limits</u>
Arsenic	44	1.8	0.95	50	50	1
Cadmium	0.26	0.29	2.5	10	1.8	0.65
Chromium	1.6	2.0	0.90	50	16	98
Copper	50	2.2	6.8		9.2	6.5
Mercury	0.20	0.024	0.0042	2	2.4	0.012
Zinc	39	70	65		65	59
Tributyltin	12	0.015	0.017		0.08	0.02

interstitial water and the first-step leachate to regulatory limits issued by the California Regional Water Quality Control Board and to maximum contaminant levels (MCLs) established under the Safe Drinking Water Act. MCLs were not exceeded by any of the leachate data. Effluent or discharge limits for copper and tributyltin were exceeded in at least one test for the upper and lower sediments. Effluent limits for cadmium and zinc were also exceeded for the lower sediment. Receiving water limits were exceeded for all contaminants listed in Tables 44 and 45 except for chromium for both sediments and zinc in the lower sediment.

Environmental impacts are often assessed on the basis of mass flux of contaminants from a disposal site. Contaminant mass fluxes for leachate from Oakland Harbor sediment were estimated using leachate quality from laboratory testing and leachate flows from the HELP model. Tables 46 and 47 present flux estimates for upper and lower sediment, respectively. The scenario used for this analysis (E) is the levee alternative, which represents a worst case because of the greater leachate flows predicted for the lower sediment by the HELP model. Leachate concentrations were selected as the greatest value among the first-step anaerobic leachate, the first-step aerobic leachate, or the interstitial water concentration. These tables illustrate the decrease in flow, and hence contaminant release, between the first and the tenth year. Comparing the flux to the contaminant mass in the bulk sediment shows that a small fraction of the total mass is estimated to be lost through this pathway using this conservative approach.

Estimates from the CDF scenarios can be developed in a manner similar to those presented in Tables 46 and 47 using the percolation volumes from Table 43. A CDF with no controls (Scenario A or B) would produce contaminant fluxes of about one third of the 10-year values shown in Tables 46 and 47. CDF Scenario D with leachate controls would reduce the contaminant fluxes shown in Tables 46 and 47 by about 97 percent because the total leachate volume would be reduced from 390,000 cu ft to 11,000 cu ft. Most of the reduction in percolation volume for Scenario D results from the drainage layer associated with the liner system. The HELP model indicates that the volume collected by the leachate collection system in year 10 is 210,000 cu ft (see Appendix D). To reduce overall contaminant flux from the disposal operation, treatment of this leachate must be provided. The volume can be reduced by placement of a cover of lower permeability on top of the dredged material.

Table 46  
Worst-Case Flux Estimates for Leachate  
from Oakland (Upper) Harbor Sediment

<u>Constituent</u>	<u>Sediment Concen- tration mg/kg</u>	<u>Total Mass Contaminant kg</u>	<u>Leachate Concen- tration µg/l</u>	<u>Contaminant Flux, Year 1 kg/year</u>	<u>Contaminant Flux, Year 10 kg/year</u>
Arsenic	10	540	43	0.3	0.00005
Cadmium	0.96	51	0.89	0.006	0.000001
Chromium	320	17,000	2.4	0.02	0.000003
Copper	100	5,000	46	0.3	0.00005
Mercury	1	54	0.08	0.0005	0.00000009
Zinc	220	12,000	29	0.2	0.00003
Tributyltin	0.7	38	16	0.1	0.00002

Notes:

Scenario E1, upper sediment placed in 3-ft lift.

Calculations use 1.2E+08 lb (5.4E+07 kg) dry sediment, 240,000 cu ft percolation for year 1, and 5,770 cu ft percolation for year 10.

Table 47  
Worst-Case Flux Estimates for Leachate  
from Oakland (Lower) Harbor Sediment

<u>Constituent</u>	<u>Sediment Concen- tration mg/kg</u>	<u>Total Mass Contaminant kg</u>	<u>Leachate Concen- tration µg/l</u>	<u>Contaminant Flux, Year 1 kg/year</u>	<u>Contaminant Flux, Year 10 kg/year</u>
Arsenic	5.9	2,700	44	2	0.02
Cadmium	0.37	170	2.5	0.1	0.001
Chromium	590	270,000	2.0	0.1	0.001
Copper	41	19,000	50	3	0.03
Mercury	0.54	240	0.2	0.01	0.0001
Zinc	78	35,000	70	4	0.04
Tributyltin	0.035	16	12	0.61	0.007

Notes:

Scenario E2, lower sediment placed in 3-ft lift.

Calculations use 1.0E+09 lb (4.5E+08 kg) dry sediment, 1,800,000 cu ft percolation for year 1, and 390,000 cu ft percolation for year 10.

Construction of an adequate toe drain system on levees prior to dredged material disposal will greatly reduce the potential groundwater impacts of contaminants in Scenario E. The hydraulic head of water from the river against the levee displaces dissolved materials laterally toward the lower lying toe drain, where a substantial portion of the leachate can be collected along with surface water. Groundwater flow on a perimeter levee with a toe drain system is illustrated in Figure 33. The magnitude of potential impacts on groundwater in Scenario E is difficult to assess, but is expected to be minor because of prolonged percolation times for one batch leaching test volume and the lateral transport of contaminants toward the toe drain. These two factors serve to decrease the flux of contaminants and dissolved solids to the freshwater aquifer, substantially reducing potential impacts such as salinity intrusion and increased contaminant concentrations in the underlying groundwater resources.

## PART VI: PLANT TEST

### Methods and Materials

#### Sediment preparation

Upon arrival at the WES, the upper and lower Oakland Harbor sediments were each placed into one of two soil lysimeters and mixed. Enough sediment was randomly collected from each soil lysimeter using a shovel to fill one 208-l steel barrel of each sediment. Soils from two reference sites, 7th Street and Twitchell Island, were also collected and stored in steel barrels. The sediments and soils were all stored in a walk-in cold room at 4 °C until testing began.

The two Oakland Harbor test sediments were poured into separate aluminum drying flats placed on the floor in the greenhouse and thoroughly mixed (Figure 13). Immediately after mixing, four 9.5-l samples were randomly taken from each flat and placed in buckets. Each bucket was sampled for chemical analysis of the wet sediment. Lids were placed on the buckets, and the buckets were placed back in the cold room until the time of testing. The sediments contained in the drying flats were then allowed to air-dry (Figures 14 and 15). The sediments were turned daily with a Teflon spatula. After drying 3 weeks, the sediments were ground in a hammer mill to pass a 2-mm screen. The ground sediment was returned to its respective drying flat and thoroughly mixed. Samples were taken of each air-dried sediment for chemical analysis. Seventy-five kilograms (oven-dry weight (ODW) basis) of each air-dried sediment was set aside for washing; the remainder was placed back into barrels.

One part air-dried sediment (5 kg ODW) and three parts of reverse osmosis (RO) purified water (15 kg) (weight to weight basis) were placed in 23-l Bain-Marie buckets (15 buckets were needed for each sediment). The sediment/water in each bucket was then mixed for 5 min every hour for 5 hr using an electric mixer. The suspension was allowed to settle overnight or until all visible suspended particles had settled out; then, the wash water was siphoned off. One-liter samples of wash water from each bucket were collected and composited for each sediment, prior to siphoning. Four samples for metals analysis and four samples for butyltin analysis were collected from the wash water composite of each sediment. The sediments were placed back into the drying flats, and the drying, grinding, and washing process was repeated until the sediments had been washed three times and dried and ground four times.

The two reference soils were also air-dried in the drying flats. Twitchell Island soil was air-dried and ground. The 7th Street reference soil contained a considerable amount of large rocks and gravel that had to be removed before processing could continue. Separation was accomplished by sieving the soil first through a 19-mm screen, then a 3.35-mm (6-mesh) screen, and last, through a 2-mm screen. One liter of screened soil was collected from each soil for laboratory analysis. The reference soils were not washed.

#### Preparation of greenhouse tests

A schematic diagram of the standard WES plant bioassay apparatus is shown in Figure 36 and described by Lee, Folsom and Engler 1982. Four upland replicates of each air-dried, unwashed sediment (to be planted with *Sporobolus virginicus*), eight replicates of air-dried, washed sediment (to be planted with *Cyperus esculentus* and *S. virginicus*), and eight replicates each of upper and lower sediment, air-dried (to be planted with *C. esculentus* and *S. virginicus*) were prepared by placing 4,500 g (ODW) of sediment (one 500-ml scoopful at a time) into each of four 7.6-l Bain-Marie containers. The remaining air-dried sediment was placed into an appropriate container (7.6-l Bain-Marie bucket) and stored until needed for subsequent chemical and/or physical analyses.

Soil moisture was maintained between 30 and 60 MPa (field capacity is 30 MPa) by checking soil moisture tensiometers in each container daily. Plants were watered when tensiometers read greater than 60 MPa (generally every other day). When watering was necessary, the outer container was filled to the sediment level of the inner container with RO or distilled water. When tensiometers read less than 40 MPa, the water was siphoned out of the outer container. Water movement continued up into the sediment by capillarity, which generally resulted in soil moistures of 10 MPa. The excess water was allowed to freely drain back to 30 MPa.

#### Greenhouse operation

The replicates were randomly placed on tables in the greenhouse. Day length of 16 hr was maintained by using light fixtures whose face was 130 cm from the top of the 22.7-l Bain-Marie container. The 130-cm height allows potential maximum plant growth to occur without contacting the light fixture or becoming so close to the light that plant tissue is damaged from excess heat. Lights were arranged in a pattern of alternating a high-pressure sodium lamp and a high-pressure multivapor metal halide lamp. Alternating the lamps provided an even photosynthetic active radiation (PAR) distribution pattern.

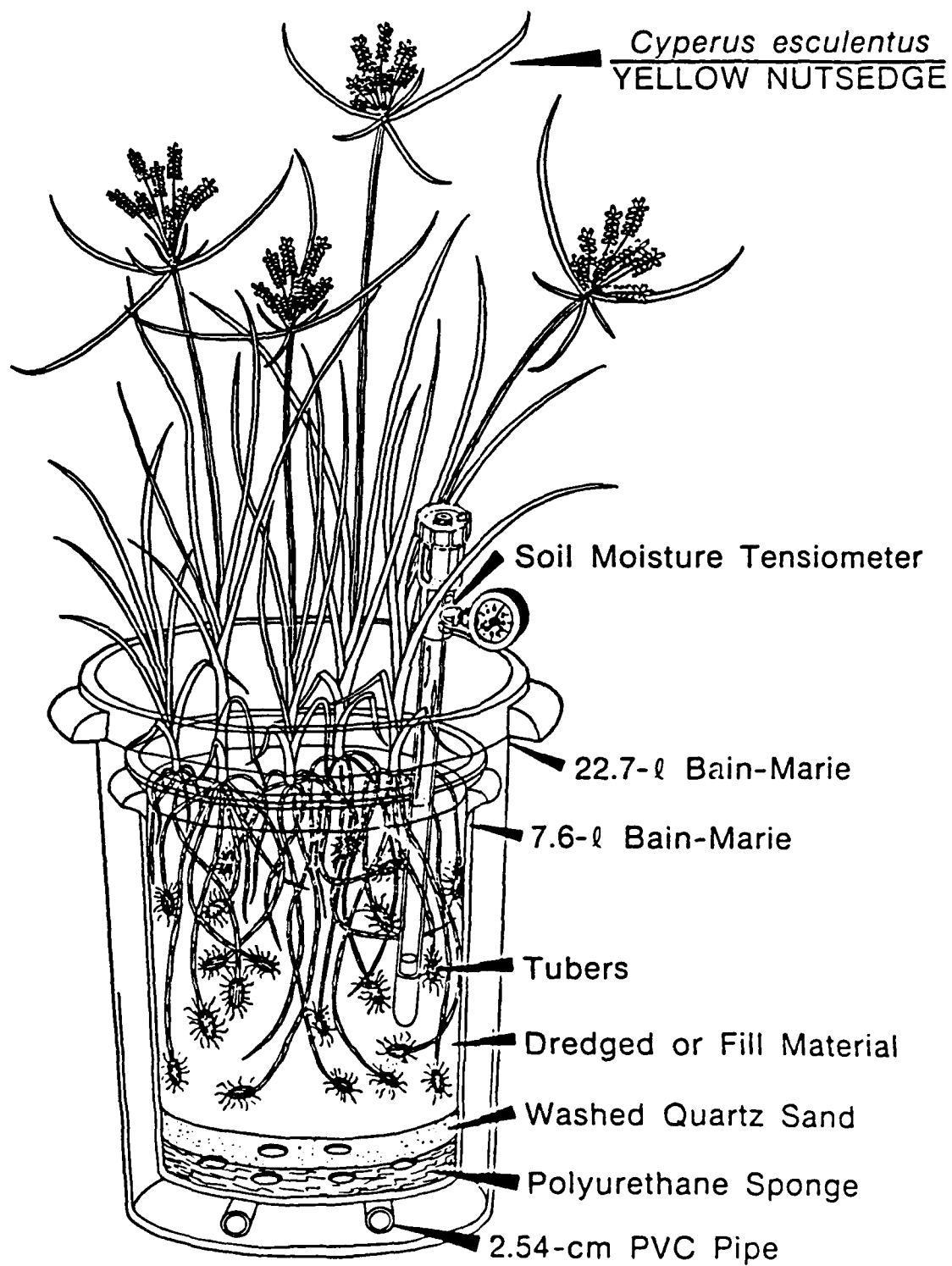


Figure 36. Plant bioassay apparatus

The PAR was 1,200  $\mu$ Einsteins per meter squared. The temperature of the greenhouse was maintained at  $32.2 \pm 2$  °C maximum during the day and  $21.1 \pm 2$  °C minimum at night to simulate a summer environment. Relative humidity was maintained as closely as possible to 100 percent, but never less than 50 percent.

#### Planting and growing techniques

The plants used in the WES plant bioassay were *C. esculentus* and *S. virginicus*. Each replicate of appropriate sediment was planted with either four sprigs of *S. virginicus* or four germinated tubers of *C. esculentus*. Plants were allowed to grow for 45 days from the time of planting (Figures 37 and 38).

#### Harvesting

After 45 days, the aboveground *C. esculentus* plant material (90 days for *S. virginicus*) from each replicate was cut 5 cm above the sediment surface with stainless steel scissors (Figure 39), and a total fresh weight was determined. Half of the harvested plant material was placed into a labeled brown paper bag, perforated by several holes to allow water vapor to escape during drying. The bags containing the harvested plant material were dried to a constant weight in a forced-air drying oven at  $70 \pm 2$  °C (generally 4 or 5 days). All dried tissue was removed from the bags and weighed. The other half of the live aboveground plant tissue was placed in hexane-washed glass bottles and frozen until extraction and butyltin analysis. Percent moisture (ODW) was determined on a small subsample of the aboveground plant tissue. Total plant yields (ODW) were determined from the percent oven-dry plant tissue  $\times$  total fresh tissue weight.

Sediment particle-size distribution. Particle size of the sediments was determined on air-dried sediments using the method of Day (1956), as modified by Patrick (1958).

Moisture holding capacity. Moisture holding capacity was accomplished using a pressure plate apparatus at 1/3, 5, and 15 bar pressure (Klute 1965).

Electrical conductivity and salinity. Electrical conductivity (EC) was determined on saturated extracts of each air-dried sediment using the method of Rhoades (1982). EC was also determined on the original, flooded upper and lower Oakland Harbor sediments. The extracts were measured on a YSI model 32 conductance meter to determine EC (mmhos/cm). The EC of each sediment wash water after washing was also determined. Salinity was measured on the



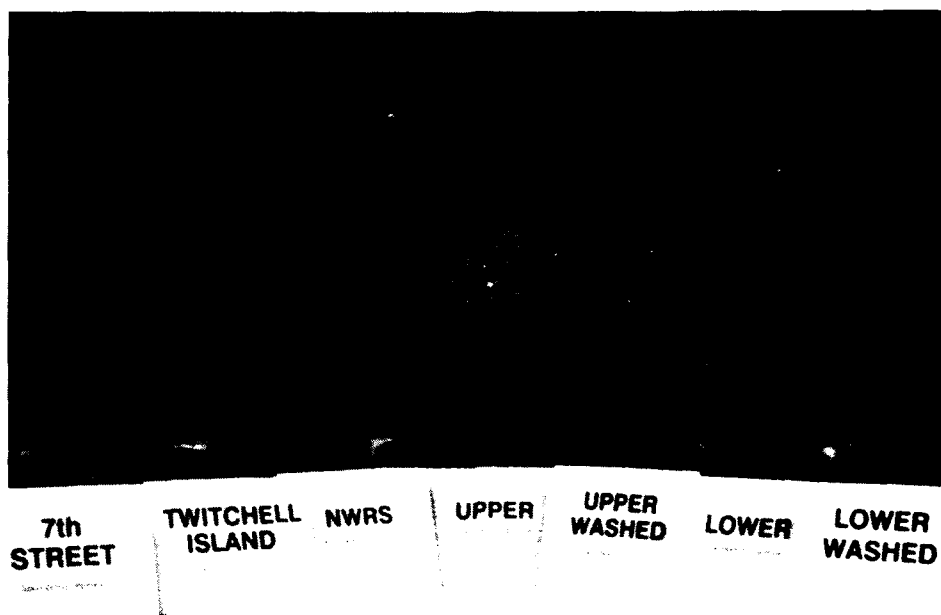


Figure 37. Appearance of *Sporobolus virginicus* growing in various test substrates

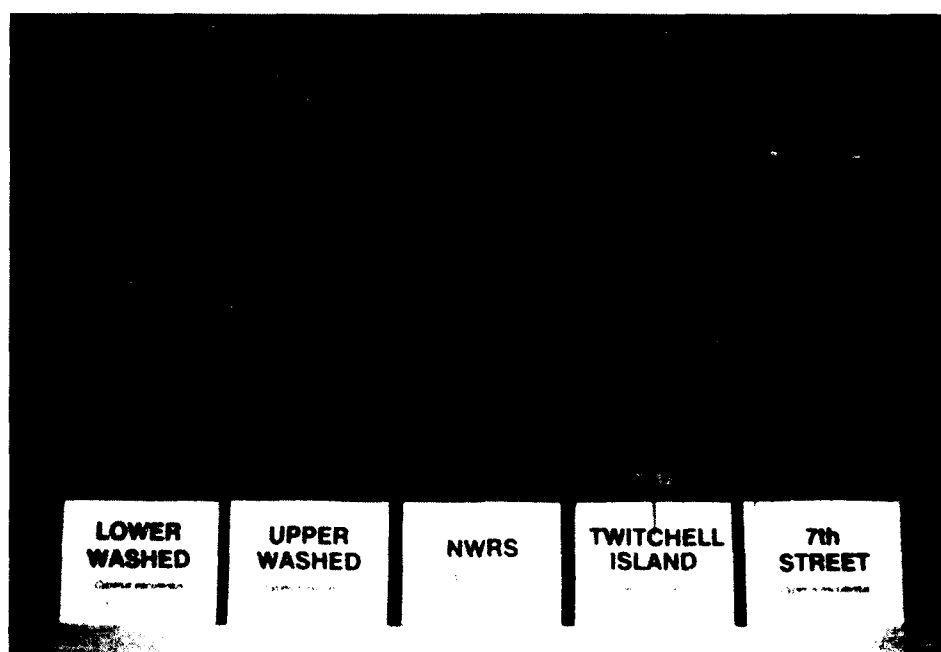


Figure 38. Appearance of *Cyperus esculentus* growing in various test substrates



Figure 39. Harvesting of plants after growth in various test substrates

saturation extracts and wash water samples using a model 10419 hand refractometer (American Optical, Buffalo, NY).

Total heavy metal content. One gram (ODW) (weighed to the nearest 0.001 g) of upland air-dried sediment was placed into a 100-ml micro-Kjeldahl flask. Ten milliliters of concentrated nitric acid was added to the flask and its contents, and allowed to sit overnight. A tertiary acid mixture of a 2:1:5 ratio of perchloric acid ( $\text{HClO}_4$ ), sulfuric acid ( $\text{H}_2\text{SO}_4$ ), and nitric acid ( $\text{HNO}_3$ ) was prepared by adding the following volumes of acid to a 1-l bottle, swirling to mix, and then putting into a repipet:

200 ml	concentrated $\text{HClO}_4$
100 ml	concentrated $\text{H}_2\text{SO}_4$
500 ml	concentrated $\text{HNO}_3$

Twenty milliliters of the tertiary acid mix was added to the contents of the flask, and the flask was swirled to wet its contents. Then the flask was placed on a digestion rack. The mixture was heated until the mixture started to boil, and the heat was slightly increased. The nitric acid distilled as a yellowish gas. When all of the perchloric acid was gone, the digestion was complete and only the sulfuric acid was left (approximately 2 ml). The flask was removed from the digestion rack and allowed to cool to room temperature.

Twenty milliliters of distilled water was added to the solution, which was then quantitatively filtered through a Whatman No. 42 filter paper contained in a long-neck funnel in a 50-ml volumetric flask. Distilled water was used to wash any white, gelatinous precipitate on the filter paper in the funnel that may have formed during the digestion. This wash water was allowed to filter into the 50-ml volumetric flask as well. The solution was diluted to volume with distilled water and then analyzed for heavy metals.

Total heavy metal sediment concentration was calculated using the formula

$$\begin{aligned}\text{Metal concentration} &= \frac{\text{Solution metal concentration} * \text{Dilution volume}}{\text{Grams ODW soil actually digested}} \\ &= \frac{\mu\text{g/ml} * 50 \text{ ml}}{\text{Grams soil actually digested}} \\ &= \frac{\mu\text{g metal}}{\text{Grams soil}}\end{aligned}$$

Blanks and National Bureau of Standards Standard Reference Material (NBS SRM) 1645 were also digested with the above procedure. The blank concentrations were subtracted from the solution concentrations before calculating the metal concentrations using the above formula.

Flooded DTPA. A 50.0-g (weighed to the nearest 0.001 g) ODW-basis subsample of the original, flooded sediment was weighed into a 500-ml polycarbonate centrifuge bottle and centrifuged at 4 °C and 13,701 \* g† (9,500 rpm) for 30 min. The supernatant was discarded. To the sediment in the centrifuge bottle was added 250 ml of 0.005 M DTPA + 0.01 M calcium chloride + 0.1 M triethanolamine solution (Lee et al. 1978, Lee et al. 1983) buffered at pH 7.3. The bottle was sealed and shaken for 24 hr, then centrifuged as before. The supernatant was poured into a polyethylene bottle, and the liquid was stored at 4 °C until the time of chemical analysis.

Upland DTPA. The procedure involves adding 250.0 ml of the DTPA extraction solution to 50.0 g (ODW) of the air-dried sediment in a 500-ml polycarbonate centrifuge bottle that was then shaken for 24 hr. The sediment/solution

---

† The 500-ml centrifuge head loaded with 500-ml centrifuge bottles containing sediment spun at 9,500 rpm for 30 min is equal to 13,700 times the acceleration due to gravity (g).

was centrifuged and processed as described above. Heavy metal concentrations were determined using Flame Atomic Absorption (AA) or Heated Graphite Furnace Atomic (HGA) spectrophotometry.

DTPA extractable heavy metals were calculated using the following formula:

$$\begin{aligned}\text{DTPA metal concentration} &= \frac{(\text{DTPA extracting solution metal concentration}) * \text{Extracting solution volume}}{\text{Weight of ODW soil actually extracted}} \\ &= \frac{\text{Micrograms/milliliter} * 250 \text{ ml}}{\text{Grams soil}} \\ &= \frac{\text{Micrograms metal}}{\text{Grams soil}}\end{aligned}$$

Blanks were also subjected to the DTPA extraction procedure. Metal concentrations of the blanks were subtracted from the extracting solution concentration before performing the above calculation.

Flooded and upland pH. Ten grams (ODW) (weighed to the nearest 0.001 g) of original wet or upland sediment was weighed into a tall 50-ml Pyrex glass beaker. Twenty milliliters of distilled water was added, and the mixture was stirred with a polyethylene rod until all dry particles were saturated. The suspension was stirred for 1 min every 15 min for 45 min with a magnetic stirrer. After 45 min with the stirrer off, the pH electrode was placed into the solution above the surface of the sediment and the pH determined (Folsom, Lee, and Bates 1981).

Organic matter. Organic matter was determined by weight loss on ignition at 550 °C on upland sediment. Procedure No. 209E (American Public Health Association 1976) was used for this test. A 5-g subsample (ODW) of the sediment was weighed to the nearest 0.001 g and dried at 105 ± 2 °C until constant weight. Five grams (weighed to the nearest 0.001 g) of the oven-dried sediment was then combusted at 550 ± 5 °C for 24 hr in a muffle furnace. The sample was allowed to cool to room temperature and weighed to the nearest 0.001 g. Weight loss on ignition was calculated and reported as percent organic matter (%OM). The formula below was used for the calculation of percent organic matter:

$$\%OM = \frac{\text{Weight oven-dried sediment} - \text{Weight combusted sediment}}{\text{Weight oven-dried sediment}} * 100$$

Plant material digestion and analysis. The dried leaves were ground in a small Wiley mill. Two grams (weighed to the nearest 0.001 g) of the ground leaf tissue were digested using the tertiary acid digestion procedure described for soils and sediments except that 2.0 g ODW tissue was used rather than 1.0 g of soil. The diluted digestates were analyzed for heavy metals by AA and HGA. Results of the digestion are calculated using the equation:

$$\begin{aligned} \text{Tissue metal concentration} &= \frac{\text{Solution metal concentration} * \text{Dilution volume}}{\text{ODW leaf tissue digested}} \\ &= \frac{\text{Micrograms metal/ml} * 50 \text{ ml}}{\text{Grams tissue}} \\ &= \frac{\text{Micrograms metal}}{\text{Grams tissue}} \end{aligned}$$

Blanks and NBS SRM 1572 were also digested. The blank metal concentration was subtracted from the solution metal concentration before performing the calculations.

The plant material, wash water, and sediments were analyzed for butyltin species using the method of Unger et al. (1986) and are reported on a nanogram per liter basis. (A detailed description of the butyltin methods was given in the Methods and Materials section of Part II, Sediment Characterization.) All analytical results are presented in Appendix E.

## Results and Discussion

### Effect of sediment washing on butyltin

Upper and lower Oakland sediments were washed and air-dried to simulate a weathered, oxidized upland disposal environment. By washing the sediment with water and examining the contaminant content of the wash water, it was possible to estimate the potential contaminant loss from upland sediments subjected to several years of environmental weathering. Butyltin was not lost through washing, as little or no butyltin was detected in wash water after sediment washing (Table 48). Air-drying the sediment, but not washing,

Table 48  
Wash Water Butyltin Concentrations (ng/l) from  
Upper and Lower Oakland Harbor

Butyltin Species	Wash Water Number		
	1	2	3
<u>Upper Oakland</u>			
Tetra	LTDL*	LTDL	LTDL
Tri	BBC**	LTDL	LTDL
Di	BBC	LTDL	1.08
Mono	13.23	8.50	LTDL
Total	BBC	LTDL	3.67
Percent recovery	38.00	36.50	47.75
<u>Lower Oakland</u>			
Tetra	LTDL	LTDL	LTDL
Tri	BBC	LTDL	LTDL
Di	BBC	LTDL	18.98
Mono	15.55	LTDL	7.55
Total	BBC	LTDL	12.42
Percent recovery	40.0	58.33	43.50

\* Less than detectable limit.

\*\* Below blank concentration.

reduced upper Oakland Harbor sediment butyltin content (except for dibutyltin) (Table 49). Only about 24 percent of total butyltin remained in the sediment after the sediment was air-dried and washed. Butyltin content of lower Oakland sediment was not affected by drying, probably due to much lower butyltin content and to the aerobic bacteria and subsequent aerobic degradation being much less in the lower Oakland Harbor sediment (Seligman, Valkirs, and Lee 1986) than in the upper Oakland Harbor sediment.

Little or no desorption of butyltin from sediments into the wash water is consistent with the findings of Seligman, Valkirs, and Lee (1986) in studies of tributyltin degradation in San Diego Bay, California, waters. They found that only 4 to 6 percent of added <sup>14</sup>C-labeled tributyltin was adsorbed by sediment particles with the remainder remaining in solution. A reduced sediment content of butyltin following air-drying was most probably due to a combination of photolysis and microbial biodegradation (Seligman, Valkirs, and Lee (1986). Maguire and Tkacz (1985) found similar results in their studies of tributyltin in water and sediment from Toronto Harbor. Reduction of butyltin due to photolysis and biodegradation was highly likely since the

Table 49  
Sediment Concentration ( $\mu\text{g/g}$ ) of Butyltin from Upper and Lower Oakland  
 Harbor After Being Air-Dried and Washed

<u>Butyltin Species</u>	<u>Oxidation/Wash Status</u>		
	<u>Original Wet</u>	<u>Air-Dried</u>	<u>Air-Dried + Washed</u>
<u>Upper Oakland</u>			
Tetra	0.0280a*	0.0023b	0.0053ab
Tri	1.2820a	0.2745b	0.3248b
Di	0.4152a	0.1833a	0.1388a
Mono	0.1707a	0.0134b	0.0213b
Total	1.8960a	0.4475b	0.4873b
Percent recovery	62.3a	41.3b	54.5ab
<u>Lower Oakland</u>			
Tetra	LTDL**	LTDL	LTDL
Tri	0.0935a	0.0528a	0.0700a
Di	0.0280a	0.0280a	0.0323a
Mono	0.0273a	0.0049a	0.0095a
Total	0.1328a	0.0878a	0.1115a
Percent recovery	49.8a	46.0a	27.5a

\* Mean of four replicates. Means in a row followed by the same lowercase letter are not statistically different at  $P = 0.05$ .

\*\* Less than detectable limits.

sediments in this study were exposed to warm temperatures and high light intensity during the drying process.

#### Electrical conductivity, salinity, and pH

The simulated weathering process lowered EC (i.e below 12 mmhos/cm) and salinity (Table 50) enough to support plant growth of *C. esculentus*. Reducing EC to a point such that *C. esculentus* would grow on the Oakland sediments would allow the use of *C. esculentus* (yellow nutsedge) as an index plant to link existing agronomic data to that of WES data (van Driel, Smilde, and van Luit 1985; Folsom, Davis, and Houghton 1988; Folsom and Houck 1990). Otherwise, the upland estuarine index plant, *S. virginicus* would have to be used. Only relative differences between uptake in *S. virginicus* from the reference sediments compared to the test sediments could be made since no database is available for *S. virginicus*. As part of a recent study, it was found that growth of *C. esculentus* was not sensitive to soil pH in the range from 5.0 to 8.0 (Folsom et al. 1988a). Since sediment pH was not reduced to less than 5.0 by the simulated weathering process, plant growth and plant

Table 50

Wash Water pH, Electrical Conductivity (EC), Salinity, Suspended Solids (SS), and Heavy Metals in Sediments from Upper and Lower Oakland Harbor

<u>Metal</u>	<u>Wash Water Number</u>		
	<u>1</u>	<u>2</u>	<u>3</u>
<u>Upper Oakland</u>			
Cadmium, $\mu\text{g/ml}$	0.00089a*	0.00013b	LTDL**
Chromium, $\mu\text{g/ml}$	0.00365a	0.00158b	0.00333a
Mercury, $\mu\text{g/ml}$	0.00004a	0.00001b	0.00001b
Nickel, $\mu\text{g/ml}$	LTDL	LTDL	LTDL
Zinc, $\mu\text{g/ml}$	LTDL	LTDL	LTDL
pH	7.27c	7.34b	8.82a
EC, mmhos/cm	9.03a	4.93b	4.16c
Salinity, ppt	8.0a	4.0b	2.0c
SS, mg/l	66.8a	24.5b	65.9a
<u>Lower Oakland</u>			
Cadmium, $\mu\text{g/ml}$	0.00046a	0.00013c	0.00035b
Chromium, $\mu\text{g/ml}$	0.00442b	0.00485b	0.02167a
Mercury, $\mu\text{g/ml}$	0.00004b	0.00001c	0.00015a
Nickel, $\mu\text{g/ml}$	LTDL	LTDL	LTDL
Zinc, $\mu\text{g/ml}$	LTDL	LTDL	LTDL
pH	7.01a	7.02a	6.66b
EC, mmhos/cm	4.42a	1.61b	0.87c
Salinity, ppt	5.0a	1.67b	0.0c
SS, mg/l	38.3b	33.1c	120.8a

\* Mean of four replicates. Means in a row followed by the same lowercase letter are not statistically different at  $P = 0.05$ .

\*\* Less than detectable limits.



uptake of contaminants should not be inhibited. Patrick (1990) also reported that the pH of sediment from Oakland Harbor did not show extensive reduction in soil pH when placed on Twitchell Island levee. Only 5 percent of the samples collected in the field showed pH values at 5.0.

#### Total metals

Air-dried upper Oakland Harbor sediment generally had the greatest total cadmium, while total cadmium in the other sediments was not different from each other (Table 51). Total mercury was also greatest in upper Oakland Harbor sediment, next was lower Oakland Harbor sediment, and 7th Street and Twitchell Island soils were least. Total chromium was equal in the upper and lower Oakland Harbor sediments, while both were greater than 7th Street and Twitchell Island soils. Total zinc was greatest in 7th Street soil and least in Twitchell Island soil.

#### DTPA metals

DTPA-extractable heavy metals in original, wet Oakland Harbor sediments were generally less than that in air-dried Oakland Harbor sediments (Table 52). DTPA-extractable metals from the upper Oakland Harbor sediment were greater than those from Twitchell Island soil for cadmium, chromium, and zinc; nickel in the upper Oakland Harbor sediment and Twitchell Island soil was not different.

The DTPA extraction data indicated that potential mobility of zinc and cadmium into the environment through freshwater plant uptake may be more from air-dried and weathered sediments than that from the original, wet sediments.

#### Plant yield of *Sporobolus virginicus*

Plant yield of *S. virginicus* grown on both Oakland test sediments and 7th Street soil were lower than plant yield of *S. virginicus* grown on Twitchell Island soil (Table 53). Plant yield from the upper Oakland sediment was reduced 65.9 percent while that grown on the lower Oakland Harbor sediment was reduced 79.2 percent. Plant growth on 7th Street soil was reduced 68.4 percent. Washing reduced the plant growth of *S. virginicus* on the upper Oakland Harbor sediment but not on the lower Oakland Harbor sediment.

#### Plant yield of *Cyperus esculentus*

The same trend of plant yield reduction on the sediments for *S. virginicus* was found for *C. esculentus* (Table 53).

#### Metal uptake by *Sporobolus virginicus*

Heavy metal content of *S. virginicus* grown on the Oakland sediments and from 7th Street soil was generally less than from plants grown on Twitchell

Table 51

Total Sediment Concentration of Heavy Metals, pH, Electrical  
Conductivity (EC), and Salinity as Affected by Washing

<u>Metal or Parameter</u>	<u>Original Wet</u>	<u>Air-Dried</u>	<u>Air-Dried + Washed</u>
<u>Upper Oakland</u>			
Cadmium, µg/g	1.380a*	0.6471bA**	0.718b
Chromium, µg/g	218.8a	156.9cA	171.9b
Mercury, µg/g	8.382a	1.456bA	1.828b
Nickel, µg/g	114.7a	88.1bA	89.6b
Zinc, µg/g	239.0a	171.9bB	161.1b
pH	7.88a	7.47b	6.74c
EC, mmhos/cm	33.3b	55.3a	11.2c
Salinity, ppt	24.8	ND†	8.00
<u>Lower Oakland</u>			
Cadmium, µg/g	0.4202a	0.2346bB	0.2195b
Chromium, µg/g	188.5a	154.9bA	189.5a
Mercury, µg/g	3.546a	0.560bB	0.560b
Nickel, µg/g	68.0a	54.0bA	51.8b
Zinc, µg/g	99.0a	72.3bC	63.0b
pH	8.19a	7.62b	6.78c
EC, mmhos/cm	29.8b	36.8a	3.70c
Salinity, ppt	21.8	ND	2.0
<u>7th Street</u>			
Cadmium, µg/g		0.2983B	
Chromium, µg/g		99.80B	
Mercury, µg/g		0.0097C	
Nickel, µg/g		70.30A	
Zinc, µg/g		335.7A	
pH		7.50	
EC, mmhos/cm		3.99	
<u>Twitchell Island</u>			
Cadmium, µg/g		0.3181B	
Chromium, µg/g		106.9B	
Mercury, µg/g		0.0296C	
Nickel, µg/g		61.10A	
Zinc, µg/g		82.90C	
pH		4.66	
EC, mmhos/cm		0.71	

\* Mean of four replicates. Means in a row followed by the same lowercase letter are not statistically different at  $P = 0.05$ .

\*\* Means between air-dried sediments and soils followed by the same uppercase letter are not statistically different at  $P = 0.05$ .

† Not determined.

Table 52

DTPA Extract Concentration ( $\mu\text{g/g}$ ) of Heavy Metals in Sediments from Oakland  
and Soils from 7th Street and Twitchell Island as Affected by Washing

<u>Metal</u>	<u>Oxidation/Wash Status</u>		
	<u>Original Wet</u>	<u>Air-Dried</u>	<u>Air-Dried + Washed</u>
<u>Upper Oakland</u>			
Cadmium	0.2471aB*	0.5511aA**	0.5053a
Chromium	0.3407a	0.2804bA	LTDL†
Mercury	LTDL	LTDL	LTDL
Nickel	5.410a	4.676aA	5.190a
Zinc	38.7c	69.73aA	53.7b
<u>Lower Oakland</u>			
Cadmium	0.1675b	0.2273aB	0.1800b
Chromium	LTDL	0.0098aC	0.0146a
Mercury	LTDL	LTDL	LTDL
Nickel	3.282a	1.904c	1.849b
Zinc	24.3a	23.74aB	13.5b
<u>7th Street</u>			
Cadmium		0.1396C	
Chromium		0.0882B	
Mercury		LTDL	
Nickel		1.898C	
Zinc		34.21B	
<u>Twitchell Island</u>			
Cadmium		0.235C	
Chromium		0.0199C	
Mercury		LTDL	
Nickel		9.052A	
Zinc		8.318C	

\* Mean of four replicates. Means in a row followed by the same lowercase letter are not statistically different at  $P = 0.05$ .

\*\* Means of air-dried sediments and soils followed by the same uppercase letter are not statistically different at  $P = 0.05$ .

† Less than detectable limits.

Table 53

Yield of *Sporobolus virginicus* and *Cyperus esculentus* Grown on Sediments  
from Oakland Harbor, 7th Street, and Twitchell Island

<u>Sediment</u>	<u>Yield (g)</u>		<u><i>C. esculentus</i> Washed</u>
	<u><i>S. virginicus</i> Not Washed</u>	<u>Washed</u>	
Upper Oakland	10.23Bb*	14.22Aa**	20.69B
Lower Oakland	6.24BCa	4.41Ba	6.47C
7th Street	3.48C	NA†	5.69C††
Twitchell Island	30.02A	NA	42.06A††

\* Mean of four replicates. Means in a row followed by the same uppercase letter are not statistically different at  $P = 0.05$ .

\*\* Means in a row followed by a lowercase letter are not statistically different at  $P = 0.05$  as determined using the paired t-test.

† Not applicable. Estuarine species normally would not be planted on freshwater soils.

†† The freshwater soils were not washed.

Island soil except for zinc (Table 54). Washing the Oakland sediments resulted in an expected increased plant uptake of cadmium, chromium, and nickel (Folsom, Lee, and Bates 1981). However, total plant uptake of these metals by *S. virginicus* grown on the test sediments was less than that of plants grown on Twitchell Island soil (Table 55).

Metal uptake by *Cyperus esculentus*

Heavy metal content of *C. esculentus* was greater from the Oakland test sediments and 7th Street soil compared to Twitchell Island soil for cadmium; zinc, nickel, and mercury were lower; and chromium was the same (Table 54). However, total plant uptake of heavy metals by *C. esculentus* grown on the test sediments was not greater for any metal compared to total plant uptake from Twitchell Island soil.

The plant heavy metal data indicate that as the weathering process progresses and the salinity of the estuarine sediments is reduced sufficiently to allow growth of freshwater species, plant tissue content of cadmium would increase to levels exceeding the action level of 0.1 ppm cadmium fresh weight\* for leafy vegetables (World Health Organization 1972) and both wheat

---

\* 0.1 ppm fresh weight approximately corresponds to 1.0  $\mu\text{g/g}$  on an oven-dry weight basis.

Table 54

Heavy Metal Tissue Content ( $\mu\text{g/g}$ ) in *Sporobolus virginicus* and *Cyperus*  
*esculentus* Grown on Sediments from Oakland Harbor and on Soils  
from 7th Street and Twitchell Island

<u>Sediment</u>	<u>Cd</u>	<u>Cr</u>	<u>Hg</u>	<u>Ni</u>	<u>Zn</u>
<u><i>S. virginicus</i> - Air-Dried (Not Washed)</u>					
Upper Oakland	0.4556B*	0.1457B	LTDL**	2.952B	44.19B
Lower Oakland	0.3538B	0.1960B	0.0574A	3.072B	39.24B
7th Street	0.4866B	0.0386B	0.0446A	1.160C	64.74A
Twitchell	0.7402A	1.236BA	0.0365A	4.896A	31.17C
<u><i>S. virginicus</i> - Air-Dried (Washed)</u>					
Upper Oakland	0.6841A†	0.9075A	LTDL	4.012A	35.58A
Lower Oakland	0.6005A	0.6814A	LTDL	3.207A	45.43A
<u><i>Cyperus esculentus</i> - Air-Dried (Washed)</u>					
Upper Oakland	4.644A*	0.6084A	0.0438AB	5.085C	137.6A
Lower Oakland	3.373B	0.8340A	0.0381AB	7.359B	115.2B
7th Street	0.9209C	0.4492A	0.0138B	3.252D	133.3A
Twitchell	3.592B	0.3114A	0.0681A	10.03A	101.4C

\* Mean of four replicates. Means in a column within each species followed by the same uppercase letter are not statistically different at  $P = 0.05$ .

\*\* Less than detectable limits.

† Means in a column followed by the same uppercase letter are not statistically different at  $P = 0.05$  as determined using the paired t-test.

Table 55

Total Plant Uptake of Heavy Metals ( $\mu\text{g}/\text{pot}$ ) by *Sporobolus virginicus*  
and *Cyperus esculentus* Grown on Sediments from Oakland Harbor  
and on Soils from 7th Street and Twitchell Island

<u>Sediment</u>	<u>Cd</u>	<u>Cr</u>	<u>Hg</u>	<u>Ni</u>	<u>Zn</u>
<u><i>S. virginicus</i> - Air-Dried (Not Washed)</u>					
Upper Oakland	1.440B*	0.4603B	--	9.520B	145.5B
Lower Oakland	1.372B	0.8106B	0.2015B	11.62B	146.1B
7th Street	0.9808B	0.1032B	0.0639B	2.413B	128.7B
Twitchell	17.82A	29.97A	0.8010A	119.7A	750.3A
<u><i>S. virginicus</i> - Air-Dried (Washed)</u>					
Upper Oakland	7.830A**	10.79A	--	46.00	405.4A
Lower Oakland	5.1395A	5.010A	--	26.38A	404.4A
<u><i>Cyperus esculentus</i> - Air-dried (Washed)</u>					
Upper Oakland	90.07B*	11.75A	0.8430B	98.97B	2677B
Lower Oakland	18.52C	4.570AB	0.2075C	40.35C	632.7C
7th Street	4.343D	2.144B	0.0614C	15.21C	626.2C
Twitchell	144.7A	12.73A	3.0340A	408.7A	4120A

\* Mean of four replicates. Means in a column within each species followed by the same uppercase letter are not statistically different at  $P = 0.05$ .

\*\* Means in a column followed by the same uppercase letter are not statistically different at  $P = 0.05$  as determined using the paired t-test.

straw and wheat grain (van Driel, Smilde, and van Luit 1985). The cadmium concentration also exceeds animal feed maxima (European Community 1974). Surprisingly, even plant tissue content of cadmium from the Twitchell Island reference soil was above these criteria. If Oakland sediments are used to supplement levee stability and plant growth occurs on these sediments, plant uptake of cadmium will exceed acceptable levels for agricultural production of leafy vegetables and small grains such as wheat. Therefore, plant growth on the levees must be restricted to nonagricultural production and should be limited to grass species that minimize cadmium uptake (such as red fescue).

#### Butyltin uptake

Plant uptake of organotin is presented in Table 56. In general, plant uptake of organotin was very low. No statistical analysis of the data was attempted since there were so many replicates that had organotin concentrations below detectable limits. Organotin in *S. virginicus* grown on 7th Street and Twitchell Island air-dried but not washed soils was mostly below detectable limits, while that in *S. virginicus* grown on the air-dried but not washed Oakland Harbor test sediments was greater than detectable limits. There was more di- and mono-butyltin than tetra- or tri-butyltin in plant tissue, which indicates that degradation had occurred, thus, reducing the concentration of the toxic species tributyltin. Washing the sediments appeared to have reduced organotin levels in *S. virginicus* somewhat. This would indicate that the simulated weathering process appears to enhance the degradation of organotin. Plant uptake of organotin by *C. esculentus* was somewhat more consistent and appeared to be slightly greater than that of *S. virginicus*. Degradation of tetra- and tri-butyltin seems to have occurred within *C. esculentus* as it did within *S. virginicus*. All levels of organotin in both plant species are less than methyl and butyltin values reported for eel grass (Francois and Weber 1988) that they considered to be minimally polluted with butyltin. Therefore, plant uptake of organotin by *S. virginicus* and *C. esculentus* grown on the test sediments from Oakland Harbor is not an environmental concern and should pose no problem.

#### Plant Impact and Controls

Salinity of the dredged material will not allow freshwater plants to colonize the material initially. After the material has been weathered and

Table 56

Plant Butyltin Content ( $\mu\text{g/kg}$ )

<u>Sediment</u>	<u>Tetrabutyltin</u>	<u>Tributyltin</u>	<u>Dibutyltin</u>	<u>Monobutyltin</u>	<u>Total</u>
<u><i>Sporobolus virginicus</i> - Air-Dried (Not Washed)</u>					
Upper	0.630* (--)**††	1.670 (1.040) <sup>2</sup>	10.23 (1.592) <sup>3</sup>	2.400 (--) <sup>1</sup>	12.36 (2.370) <sup>3</sup>
Lower	0.800 (--) <sup>1</sup>	3.100 (--) <sup>1</sup>	19.5 (--) <sup>1</sup>	3.700 (--) <sup>1</sup>	27.10 (--) <sup>1</sup>
7th Street	LTDL <sup>4</sup> ††	LTDL <sup>4</sup>	LTDL <sup>4</sup>	LTDL <sup>4</sup>	LTDL <sup>4</sup>
Twitchell	LTDL <sup>4</sup>	LTDL <sup>4</sup>	0.950 (--) <sup>1</sup>	LTDL <sup>4</sup>	0.950 (--) <sup>1</sup>
<u><i>Sporobolus virginicus</i> - Air-Dried (Washed)</u>					
Upper	0.820 (--) <sup>1</sup>	1.747 (0.333) <sup>3</sup>	5.617 (1.345) <sup>3</sup>	0.490 (--) <sup>1</sup>	7.800 (1.053) <sup>3</sup>
Lower	LTDL <sup>4</sup>	LTDL <sup>4</sup>	4.250 (1.250) <sup>2</sup>	72.0 (--) <sup>1</sup>	40.25 (34.75) <sup>2</sup>
<u><i>Cyperus esculentus</i> - Air-Dried (Washed)</u>					
Upper	0.627 (0.078) <sup>3</sup>	11.25 (8.92) <sup>4</sup>	5.375 (0.606) <sup>4</sup>	1.550 (0.132) <sup>4</sup>	18.65 (9.046) <sup>4</sup>
Lower	1.178 (0.213) <sup>4</sup>	6.200 (1.645) <sup>4</sup>	15.65 (4.115) <sup>4</sup>	31.28 (9.193) <sup>4</sup>	54.30 (11.27) <sup>4</sup>
7th Street	1.005 (0.195) <sup>2</sup>	4.350 (0.850) <sup>2</sup>	8.133 (1.309) <sup>3</sup>	10.47 (2.483) <sup>3</sup>	16.62 (4.634) <sup>4</sup>
Twitchell	0.795 (0.085) <sup>2</sup>	1.270 (0.230) <sup>2</sup>	5.033 (1.235) <sup>3</sup>	0.630 (--) <sup>1</sup>	4.965 (1.858) <sup>4</sup>

\* Mean of N replicates.

\*\* Standard error of the mean.

† Superscript numeral indicates the number of replicates.

†† Less than detection limit.



undergone a reduction in salinity, it will be colonized by freshwater plants. Since sediment pH was not reduced to less than 5.0 by the simulated weathering process, plant growth and plant uptake of contaminants should not be inhibited. If Oakland sediments are used to supplement levee stability and plant growth occurs on these sediments, plant uptake of cadmium will exceed acceptable levels for agricultural production of leafy vegetables and small grains such as wheat. Therefore, plant growth on the levees must be restricted to nonagricultural production and should be limited to grass species that minimize cadmium uptake, such as red fescue. Plant uptake of organotin by *S. virginicus* and *C. esculentus* grown on the test sediments from Oakland Harbor was very low and is not an environmental concern and therefore should pose no problem. Monitoring of the plants that establish at the Twitchell Island disposal site is recommended to verify minimization of contaminant migration into plants.

## PART VII: ANIMAL TESTS

### Methods and Materials

A supply of red wiggler earthworms, *Eisenia foetida*, was obtained from a commercial bait supplier, Briggs Bait Farm, in Meridian, MS. The worms were transferred to a horse manure holding medium until used for bioassessments. The horse manure selected for the worm medium was collected from a single horse that was neither on medication nor fed materials containing contaminants above background levels. In all bioassessments, only mature, clitellate earthworms were used.

As sediments were washed, as previously described, samples of the upper and lower Oakland Harbor sediments were collected for earthworm toxicity screening tests. Three earthworms were placed in small amounts of each of the test substrates, and survival after 72 hr was recorded. The results of the toxicity screening tests were used to determine the point in the washing at which the salt concentration was low enough for earthworms to colonize and allow the earthworm bioassessment procedure to be conducted.

The WES earthworm bioassessment procedure was designed to evaluate the potential toxicity or mobility of contaminants to soil invertebrates colonizing a sediment or soil in an upland environment. The test materials were placed in transparent Plexiglas cylinders 12 in. deep and 6 in. in diameter (Figure 40). Each cylinder was closed at one end with cotton muslin cloth or Nytex mesh and filled with test substrate. The muslin-covered end of each cylinder was placed in an 8-in.-diameter plastic dish of deionized water. The water could then diffuse into the substrate, and the earthworms could move to areas of optimum moisture.

Five substrates replicated three times were used in the toxicity/contaminant mobility bioassessment: Upper Oakland Harbor sediment, Lower Oakland Harbor sediment, Twitchell Island soil (potential disposal site), 7th Street soil (potential disposal site), and Reference (horse manure holding media). Thirty grams of earthworms was added to each cylinder. After 28 days the cylinders were emptied and the worms were recovered. The earthworms from each cylinder were counted and weighed before and after depurating on moist filter paper for 24 hr. Earthworms were humanely killed by freezing in preparation for analysis.

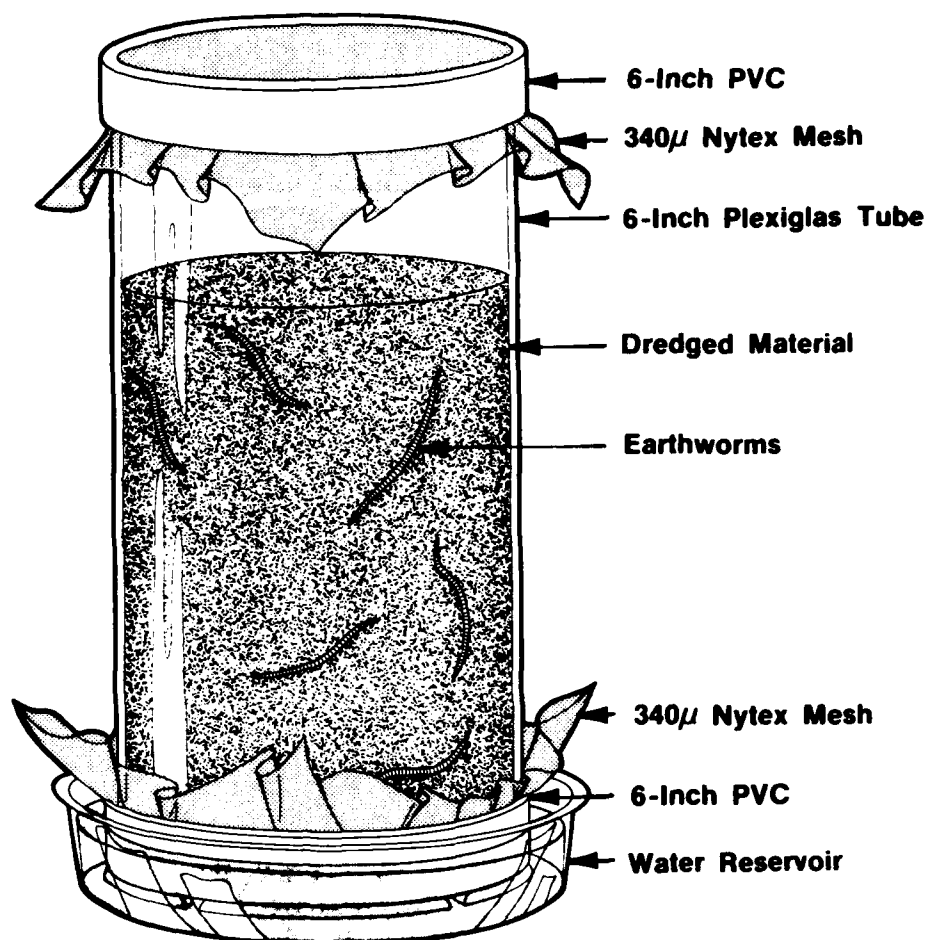


Figure 40. Earthworm bioassay apparatus

Frozen worms were shipped overnight to the analytical laboratory and analyzed for metals, butyltins, pesticides, PCBs, and PAHs. (Analytical preparations and procedures were discussed in Part II.) All analytical results are presented in Appendix F.

#### Results and Discussion

The results of the preliminary toxicity screening tests are summarized in Table 57. Unwashed upper and lower Oakland Harbor sediments were toxic to earthworms, but test animals survived in the upper sediment after two washings and in the lower sediment after one washing. Neither the Twitchell Island nor the 7th Street disposal site substrate was toxic. A summary of the toxicity and compatibility of the substrates to colonizing soil invertebrates, as

Table 57  
Earthworm 72-hr Toxicity Test

<u>Substrate</u>	<u>Treatment</u>	<u>Percent Survival</u>	<u>Mean Weight, g*</u>	
			<u>Initial</u>	<u>72 hr</u>
Upper Oakland	Unwashed	0	0.999	--
	1st wash	0	0.729	--
	2nd wash	100	1.286	1.286
	3rd wash	100	0.742	0.743
Lower Oakland	Unwashed	0	1.014	--
	1st wash	100	0.848	0.848
	2nd wash	100	1.356	1.357
	3rd wash	100	0.967	0.968
7th Street	--	100	1.132	1.132
Twitchell Island	--	100	0.982	0.982
Manure Reference	--	100	0.999	0.999

\* Mean weight (in grams) of three earthworms.

measured by both numbers and weights of worms recovered, is shown in Table 58. Worm growth and number of individuals recovered varied with the substrates. Generally, the test procedures produced sufficient biomass to permit chemical analyses. The results of the chemical analysis of the test earthworm tissues are summarized in the following tables: metals, Table 59; butyltins, Table 60; PCBs, Table 61; pesticides, Table 62; and PAHs, Table 63.

The initial toxicity tests indicated that upper and lower Oakland Harbor sediments were not toxic after washing and that colonization by upland invertebrates could begin relatively soon after disposal and after salt is leached out of sediment (Table 57). Any colonization was, however, limited by the presence of adequate food material for the soil invertebrate community. In the absence of a concomitant plant community and the resultant production of food material, the successful colonization of a dredged material disposal site by upland invertebrates is unlikely. This is clearly shown in Table 58 where the weights and numbers of the recovered earthworms are tabulated. The reference material, a good earthworm holding medium (RF), showed both good earthworm recovery and favorable weight gain. In contrast to RF, the resultant weights of harvested earthworms from the test substrates (Twitchell Island, Oakland Harbor lower and upper sediment, and 7th Street soil) indicate that

Table 58

Results of Earthworm Toxicity Test (28-Day Exposure) of Reference  
Manure, 7th Street Soil, Twitchell Island Soil, and Lower  
and Upper Oakland Harbor Sediments

<u>Replicate</u>	<u>No. Worms</u>	<u>Weight Before Depuration, g</u>	<u>Weight After Depuration, g</u>
Reference			
1	117	44.289	42.051
2	130	51.991	46.386
3	127	58.200	54.601
4	141	61.354	56.339
7th St			
1	102	27.802	27.039
2	33	11.082	10.097
3	87	18.211	17.355
4	105	27.417	26.570
Twitchell			
1	102	29.272	27.846
2	81	23.423	21.404
3	110	26.768	25.693
4	134	30.823	30.068
Lower			
1	116	27.193	25.913
2	105	18.768	17.572
3	70	26.537	24.905
4	88	20.881	19.890
Upper			
1	129	20.343	19.607
2	123	26.302	25.657
3	100	22.134	21.050
4	90	20.724	19.921

Table 59

## Concentrations of Metals in Substrates and Tissues of Bioassay

Earthworms ( $\mu\text{g/g}$  Dry Weight)

Substrate	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Upper Oakland Sediment	0.74	10.15	0.96	321.25	102.5	1.010	116.5	83.75	218
Tissue	0.10 BC*	63.1 A	7.23 A	2.02 AB	26.9 B	0.252 B	9.04 B	2.74 AB	145.2 CB
Lower Oakland Sediment	0.25	5.4	0.37	585.75	40.75	0.540	67.75	22.75	78.5
Tissue	<0.04 CD	52.5 A	7.61 A	2.71 AB	26.6 B	0.267 B	8.03 B	1.94 BC	133 D
Twitchell Island Soil	0.14	14.7	0.46	129.0	41.0	0.214	73.0	13.0	96
Tissue	<0.12 B	34.8 A	7.69 A	4.19 A	20.75 C	0.422 A	16.27 A	1.39 C	138.7 CD
7th Street Soil	0.62	24.5	0.58	348.0	563.0	0.346	65.0	120.0	303
Tissue	0.28 A	42.6 A	6.30 A	8.60 A	60.1 A	0.379 A	10.77 AB	4.50 A	151.8 A
Reference tissue	0.01 D	26.45 A	6.94 A	0.14 B	16.24 D	0.042 C	0.73 C	0.49 D	151.8 B
Initial tissue	0.05	28.5	8.65	0.59	18.0	0.079	1.03	2.92	147

\* Tissue means in each column followed by the same letter are not significantly different at  $P = 0.05$ .

Table 60

Concentrations of Organotins in Substrates and Tissues of Bioassay  
Earthworms ( $\mu\text{g}/\text{kg}$  Dry Weight as Butyltin Cations)

<u>Substrate</u>	<u>Tetra- butyltin</u>	<u>Tri- butyltin</u>	<u>Di- butyltin</u>	<u>Mono- butyltin</u>	<u>Total</u>
Upper Oakland Sediment	--	702	153	19.0	874
Tissue	4.0 A*	616.5 A	228 A	17.5 A	868 A
Lower Oakland Sediment	--	35.0	7.0	2.0	44
Tissue	<5.0 B	91.3 B	52.5 B	10.1 AB	154 B
Twitchell Island Soil	--	<0.2	<0.2	<0.2	<0.2
Tissue	<1.85 B	5.7 D	17.9 CD	4.5 BC	28 D
7th Street Soil	--	<0.2	0.2	0.2	--
Tissue	<4.9 B	21.0 C	53.5 BC	10.7 ABC	85.5 C
Reference tissue	<3.3 B	5.6 D	<12.4 D	<5.1 C	12 D
Initial tissue	<12.0	18.0	23.0	14.0	55

\* Tissue means in each column followed by the same letter are not significantly different at  $P = 0.05$ .

Table 61

Concentrations of PCBs in Substrates and Earthworm Tissues  
( $\mu\text{g}/\text{g}$  Dry Weight)

<u>Parameter</u>	<u>Upper Oakland</u>		<u>Lower Oakland</u>		<u>Twitchell Island</u>		<u>7th Street</u>		<u>Ref</u>	<u>T = 0</u>
	<u>S*</u>	<u>T</u>	<u>S</u>	<u>T</u>	<u>S</u>	<u>T</u>	<u>S</u>	<u>T</u>	<u>T</u>	<u>T</u>
Aroclor 1254	0.12	2.67 A**	0.06	2.61 A	<0.02	<1.0 B	0.04	<1.0 B	<1.0	<2.5

\* S = substrate, T = tissue.

\*\* Tissue means followed by the same letter are not significantly different at  $P = 0.05$ .

Table 62

Concentrations of Pesticides in Substrates and Earthworm Tissues( $\mu\text{g/g}$  Dry Weight)

Parameter	Oakland Harbor				Twitchell Island				7th Street	Ref	T = O T
	Upper		Lower		Island		S	T			
	S*	T	S	T	S	T					
Alpha-BHC	<0.002	<0.20	<0.002	<0.22	<0.002	<0.3	<0.002	<0.002	<0.13	<0.16	<0.08
Beta-BHC	<0.002	<0.15	<0.002	<0.16	<0.002	<0.11	<0.002	<0.002	<0.11	<0.14	<0.06
Delta-BHC	<0.002	<0.07	<0.002	<0.11	<0.002	<0.75	0.002	0.002	<0.20	<0.20	<0.07
Lindane	<0.002	<0.08	<0.002	<0.10	<0.002	<0.75	<0.002	<0.002	<0.12	<0.21	<0.05
Heptachlor	<0.002	<0.06	<0.002	<0.04	<0.002	<0.04	<0.002	<0.002	<0.09	<0.02	<0.03
Aldrin	<0.002	<0.06	<0.002	<0.10	<0.002	<0.06	<0.002	<0.002	<0.09	<0.10	<0.06
Heptachlor epoxide	<0.002	<0.12	<0.002	<0.20	<0.002	<0.07	<0.002	<0.002	<0.20	<0.08	<0.12
Endosulfan I	<0.002	<0.05	<0.002	<0.08	<0.002	<0.04	<0.002	<0.002	<0.09	<0.04	<0.08
Dieldrin	<0.002	<0.07	<0.002	<0.08	<0.002	<0.01	<0.002	<0.002	<0.06	<0.03	<0.04
4,4'-DDE**	<0.004	<0.16	<0.002	<0.24	0.003	0.26	<0.003	<0.002	0.18	<0.03	<0.04
		B†		A		A			B	C	
Endrin	<0.005	<0.09	<0.003	<0.10	<0.003	<0.03	<0.003	<0.003	<0.08	<0.05	<0.02
Endosulfan II	<0.005	<0.09	<0.003	<0.06	<0.003	<0.03	<0.003	<0.003	<0.05	<0.05	<0.02
4,4'-DDD	<0.005	<0.15	<0.003	<0.32	<0.003	<0.06	<0.003	<0.003	<0.23	<0.06	0.11
Endosulfan sulfate	<0.005	<0.07	<0.003	<0.09	<0.003	<0.07	<0.003	<0.003	<0.07	<0.10	<0.02
4,4'-DDT	<0.005	<0.55	<0.002	<0.61	<0.002	0.34	<0.002	0.010	0.56	<0.06	0.52
		A		A		B			A	C	
Methoxychlor	<0.006	<0.12	<0.004	<0.03	<0.004	<0.20	<0.004	<0.004	<0.08	<0.20	<0.03
Endrin ketone	<0.003	<0.02	<0.002	<0.06	<0.002	<0.01	<0.002	<0.004	<0.05	<0.05	<0.02
Gamma-chlordane	<0.003	<0.07	<0.002	<0.85	<0.002	<0.01	<0.002	<0.002	<0.03	<0.02	<0.05
Alpha-chlordane	<0.002	<0.06	<0.001	<0.75	<0.001	<0.01	<0.001	<0.001	<0.07	<0.05	<0.04
Toxaphene	<0.225	<1.5	<0.150	<2.0	<1.50	<1.5	<1.50	<0.150	<1.5	<1.5	<3.0

\* S = substrate, T = tissue.

\*\* Boldfaced entries indicate statistically significant detectable values observed for one or more means.

† Tissue means followed by the same letter are not significantly different at  $P = 0.05$ .



Table 63

## Concentrations of Semivolatile PAHs in Substrates and Earthworm

Tissues ( $\mu\text{g/kg}$  Dry Weight)

Parameter	Upper Oakland		Lower Oakland		Twitchell Island		7th Street		Ref T	T - O T
	S*	T	S	T	S	T	S	T		
Naphthalene	0.14	<1.0	0.06	<2.0	<0.02	<1.0	0.02	<5.0	<1.0	<2.0
Acenaphthylene	0.07	<1.0	0.02	<2.0	<0.02	<1.0	<0.02	<5.0	<1.0	<2.0
Acenaphthene	0.61	<1.0	0.21	<2.0	<0.02	<1.0	0.02	<5.0	<1.0	<2.0
Fluorene	0.15	<1.0	0.10	<2.0	<0.02	<1.0	0.01	<5.0	<1.0	<2.0
Phenanthrene	2.60	<1.5	1.10	<2.0	0.05	<2.0	0.12	<5.0	<1.0	<2.0
Anthracene	0.85	<1.0	0.30	<2.0	<0.02	<2.5	0.03	<5.0	<4.0	<2.0
Fluor- anthene**	3.40	17.7	1.20	4.9	0.26	<1.0	0.18	<5.0	<1.0	<2.0
Pyrene	3.60	31.5	1.20	18.0	0.32	<1.0	0.15	<5.0	<10.0	<2.5
Benzo(a) anthracene	1.10	<1.0	0.32	<3.5	0.07	<1.0	0.06	<5.0	<1.0	<2.0
Chrysene	1.60	<9.3	0.46	<5.9	0.12	<1.0	0.13	<5.0	<1.0	<2.0
Benzo(b&k) fluoranthene	3.00	<140.	0.75	<80.0	0.25	<55.0	0.30	<75.0	<50.0	<45.0
Benzo(a) pyrene	2.20	<7.6	0.56	<5.0	0.18	<2.0	0.10	<10.0	<3.0	<2.0
Ideno(1,2, 3-cd)pyrene	1.30	<3.5	0.35	<8.0	0.18	<3.5	0.09	<20.0	<3.5	<6.0
Dibenz(a,h) anthracene	0.21	<3.5	0.06	<8.0	0.02	<3.5	0.03	<20.0	<3.5	<6.0
Benzo(g,h,i) perylene	1.40	<3.5	0.35	<8.0	0.21	<3.5	0.07	<20.0	<3.5	<6.0

\* S = substrate, T = tissue.

\*\* Boldfaced entries indicate statistically significant detectable values observed for one or more means.

† Tissue means followed by the same letter are not significantly different at a 95-percent confidence level.

the introduced test earthworm population was on the decline. While these data indicate the failure of the substrate to provide the necessities for growth and continued maintenance, no acute toxicity occurred in any of the substrates when tested as an upland soil.

Earthworms are excellent indicators of potential bioaccumulation of contaminants by other animals. Table 64 summarizes the ability of bioassay earthworms to accumulate the contaminants included in the analytical program of this study. The individual classes of compounds are discussed in the following paragraphs.

Metal accumulation by test earthworms is summarized in Table 59. Since arsenic was relatively high in both the Reference earthworms and in the initial animals that represented the earthworms at the onset of the test, statistical differences were not observed in the four test substrates. The accumulation of cadmium was relatively uniform across the test substrates and appears to be a result of a high initial tissue content. Earthworms have been shown to readily accumulate cadmium, (Marquenie, Simmers, and Kay 1987; Gal and Bouche 1988; Kay, Scholten, and Bowmer 1988). Field and laboratory bioassessments of cadmium uptake by earthworms have been conducted in the United States, the Netherlands, and France, and have indicated that cadmium levels of approximately 40  $\mu\text{g/g}$  are common in undisturbed ecosystems. Chromium uptake in all four test substrates exceeded the reference. There is no indication from available literature that the chromium level in any of the test substrates is of biological significance as far as terrestrial soil invertebrates are concerned. The accumulation of copper by earthworms exposed to the 7th Street soil was approximately twice that of the animals exposed to the other substrates. The high copper level in the 7th Street soil is approaching a level that may cause a biological effect and, therefore, could be of concern (Folsom et al. 1988b). The earthworms in all four test substrates accumulated mercury to levels approximately an order of magnitude above those in the reference medium. Mercury uptake was lower from Oakland sediments than from the potential disposal sites. Nickel levels were relatively higher in all four test substrates than the reference soils and management may be required, although very limited data on the effects of elevated nickel in soil invertebrates are available in the literature. Lead concentrations in all substrates were higher than in reference tissues; however, the initial tissue lead was also in the range of values observed in the test substrates.

Table 64

Summary Matrix of Information on EarthwormAccumulation of Contaminants

Contaminant	No Data	Extent of Accumulation			Reference
		<Substrate	=Substrate	>Substrate	
Metals					
Ag		X			This report
As				X	This report
Cd				X	This report
Cr		X			This report
Cu		X			This report
Hg		X			This report
Mn	X		X	X	This report
Ni		X			This report
Pb		X			This report
Se	X				
Zn		X			This report
Sn	X				
Sn(tetrabutyl)	X				
Sn(tributyl)			X	X	This report
Sn(dibutyl)				X	This report
Sn(monobutyl)			X	X	This report
Pesticides					
Alpha-BHC	X				
Beta-BHC	X				
Delta-BHC	X				
Gamma-BHC (Lindane)	X				
Heptachlor		X	X		McLane, Stickel, and Newsom 1971
Aldrin	X				
Dieldrin		X	X		McLane, Stickel, and Newsom 1971

(Continued)

(Sheet 1 of 4)

Table 64 (Continued)

Contaminant	No Data	Extent of Accumulation			Reference
		<Substrate	-Substrate	>Substrate	
4,4-DDE				X	This report
Endrin	X				
4,4-DDD	X				
Endosulfan Sulfate	X				
4,4-DDT				X	This report
Methoxychlor	X				
Chlordane		X	X		McLane, Stickel, and Newsom 1971
Toxaphene	X				
Hexachlorobenzene				X	Marquenie, Simmers, and Kay 1987
PCBs					
Aroclor 1242	X				
Aroclor 1248	X				
Aroclor 1254				X	Rhett et al. 1989
Aroclor 1260					
PCB 15	X				
PCB 28				X	Rhett et al. 1989
PCB 44				X	Marquenie, Simmers, and Kay 1987
PCB 49				X	Rhett et al. 1989
PCB 52				X	Marquenie, Simmers, and Kay 1987
PCB 70				X	Marquenie, Simmers, and Kay 1987
PCB 87				X	Marquenie, Simmers, and Kay 1987

(Continued)

(Sheet 2 of 4)

Table 64 (Continued)

Contaminant	No Data	Extent of Accumulation		Reference
		<Substrate	>Substrate	
PCB 101			X	Marquenie, Simmers, and Kay 1987
PCB 138			X	Marquenie, Simmers, and Kay 1987
PCB 153			X	Marquenie, Simmers, and Kay 1987
PCB 180			X	Marquenie, Simmers, and Kay 1987
PAHs				
Naphthalene		X		This report
2-Methylnaphthalene	X			This report
Acenaphthylene		X		This report
Acenaphthene		X		This report
Fluorene		X		This report
Phenanthrene		X		This report
Anthracene		X		This report
Fluoranthene*			X	This report
Pyrene			X	This report
Benzo(a)anthracene		X		This report
Chrysene		X		Marquenie, Simmers, and Kay 1987
Benzo(b)fluoranthene		X		Marquenie, Simmers, and Kay 1987
Benzo(k)fluoranthene		X		Marquenie, Simmers, and Kay 1987
Benzo(a)pyrene		X		Marquenie, Simmers, and Kay 1987
Indeno(123c,d)pyrene		X		Marquenie, Simmers, and Kay 1987

(Continued)

(Sheet 3 of 4)

Table 64 (Concluded)

Contaminant	No. Data	Extent of Accumulation			Reference
		<Substrate	=Substrate	>Substrate	
Dibenzo(ah)anthracene		X			Marquenie, Simmers, and Kay 1987
Benzo(ghi)perylene		X			Marquenie, Simmers, and Kay 1987
3,6 Dimethylphenanthrene		X			Marquenie, Simmers, and Kay 1987
Triphenylene		X			Marquenie, Simmers, and Kay 1987
Benzo(b)fluorene		X			Marquenie, Simmers, and Kay 1987
Benzo(e)pyrene			X		Marquenie, Simmers, and Kay 1987
Benzo(j)fluoranthene	X				This report
Perylene		X			This report
3 Methylcholanthrene		X			This report
Anthanthrene		X			
Phthalateesters					
Bis(2-ethylhexyl)phthalate		X			This report
Dibenzofuran		X			This report
Radioisotopes			X		Krivolutski, Turganinova, and Mikhailtsova 1982

Tissue and substrate butyltin levels are shown in Table 60. Sediment and earthworm tissue levels of tri- and di-butyltin were most pronounced in the upper and lower Oakland sediments. The levels in both substrate and tissue from the upper Oakland sediment were highest but not toxic (Tables 57 and 58). Tributyltin appears to be readily accumulated by earthworms, but the consequences to the terrestrial food web are not known.

The results of the bioassessment for PCBs are shown in Table 61. Only one PCB mixture, Aroclor 1254, was detected in test sediment. It was detected in the upper and lower Oakland sediments. The tissue levels appeared to be slightly above initial tissue contents and statistically higher than that observed in Twitchell Island and 7th Street soils.

Although 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT were detected in the disposal site soils, they were not accumulated by the test earthworms to detectable levels in the sediments (Table 62). Earthworms appeared to accumulate these pesticides, from the Twitchell Island and 7th Street Soils; however, observed values were in the range of initial tissue contents.

Fluoranthene and pyrene were the only PAHs found above detection limits in the tissues of earthworms exposed to any of the test substrates (Table 63). Earthworms exposed to both upper and lower Oakland sediments accumulated these PAHs. Substrate and tissue concentrations of both compounds were higher in the upper Oakland sediment.

### Conclusions

The bioaccumulation of butyltin has been widely documented in the marine/estuarine environment (Table 65). No comparable data are available for the freshwater upland animal community. A wide variety of animals may colonize the dredged material following disposal. Prior to the establishment of vegetation, the site will most likely attract various gulls and terns that may even nest on the site. Species such as these do not feed onsite and can only be impacted by their physical contact with the dredged material. Large colonies of shorebirds may be difficult to manage and may result in the occurrence of common diseases (Simmers, Apfelbaum, and Bryniarski 1990). With the establishment of vegetation, the disposal site will be colonized by earthworms and other soil invertebrates that predominantly live and feed in the leaf litter produced by the plants. Some potential for metals, such as cadmium, to move

Table 65

Summary of Tributyltin (TBT) Concentrations in Sediments and  
Animals, from Available Literature

<u>Sample</u>	<u>Concentration</u>		<u>Species</u>
	<u>Sediment</u>	<u>Animal</u>	
<u>Duwamish Waterway<sup>1*</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> Sn/kg dry weight)</u>			
1	610(61)**	100(9.5)	Sole (liver)
2	1,300(290)		
3	570(83)		
<u>Seattle Waterfront<sup>1</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> Sn/kg dry weight)</u>			
1	36(3.0)	<22(25)	Sole (liver)
2	20(4.0)		
3	55(8.9)		
<u>President Point<sup>1</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> Sn/kg dry weight)</u>			
1	<0.85(0.56)	<8.4(1.0)	Sole (liver)
2	<0.86(0.24)		
3	<0.40(0.11)		
<u>Reference<sup>1</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> Sn/kg dry weight)</u>			
1	--	160(64)	Oyster (ref.)
<u>San Diego<sup>2</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> Sn/kg dry weight)</u>			
1	--	0.38(0.03)	Blue mussel
2	--	0.28(0.05)	
3	--	0.25(0.05)	
<u>Monterey Bay<sup>2</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> TBT/g dry weight)</u>			
1	--	0.28(0.14)	Blue mussel
2	--	0.02(0.003)	

(Continued)

\* Reference sources were as follows:

<sup>1</sup> Krone et al. (1989).<sup>2</sup> Short and Sharp (1989).<sup>3</sup> Rice, Espourteille, and Huggett (1987).<sup>4</sup> Linden (1987).

\*\* Number in parentheses represents one standard deviation.



Table 65 (Concluded)

<u>Sample</u>	<u>Concentration</u>		<u>Species</u>
	<u>Sediment</u>	<u>Animal</u>	
<u>Puget Sound<sup>2</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> TBT/g dry weight)</u>			
1	--	0.23(0.05)	Blue mussel
2	--	0.19(0.05)	
3	--	0.06(0.03)	
4	--	0.13(0.04)	
5	--	0.08(0.06)	
6	--	0.03(0.01)	
<u>Auke Bay<sup>2</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> TBT/g dry weight)</u>			
1	--	0.15(0.06)	Blue mussel
2	--	0.10(0.05)	
3	--	0.04(0.01)	
4	--	0.02(0.01)	
5	--	<DL	
<u>Kodiak Harbor<sup>2</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> TBT/g dry weight)</u>			
1	--	0.78(0.13)	Blue mussel
2	--	0.80(0.12)	
3	--	0.60(0.27)	
4	--	0.10(0.01)	
5	--	0.13(0.04)	
<u>Chesapeake Bay, Maryland<sup>3</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> TBT/g wet weight)</u>			
1	--	1.5	Oyster
<u>Southwest Sweden<sup>4</sup></u>			
<u>(Concentrations in <math>\mu\text{g}</math> Sn/g dry weight)</u>			
1		3.7	Blue mussel

\* Reference sources were as follows:

<sup>2</sup> Short and Sharp (1989).

<sup>3</sup> Rice, Espourteille, and Huggett (1987).

<sup>4</sup> Linden (1987).

through the herbivore food chain exists, but movement into insectivores is unlikely (Stafford et al. 1991).

No information concerning the potential movement of butyltins from soil invertebrates into the terrestrial food web exists. Insectivores and small herbivores could be sampled for butyltin content as the site is naturally colonized, or the disposal area could be planted with vegetation that deters colonization by birds and mammals.

Movement of PCBs from soil invertebrates to higher organisms such as insectivorous birds does not appear to pose any problem (Stafford et al. 1991). However, no data concerning the movement of PCBs in the herbivore food web are available.

The relatively low levels of pesticides and PAHs in bioassay earthworm tissues do not suggest the need for any management practices to isolate these compounds from food webs that may become established on the dredged material.

## PART VIII: CONCLUSIONS AND RECOMMENDATIONS

Evaluation of the results from effluent, surface runoff, leachate, and plant and animal bioassay tests indicates the need for some restrictions to be implemented at both the Twitchell Island disposal site and the 7th Street disposal site. The disposal of Oakland sediments at either site can be managed to minimize the impact to the environment associated with each site.

Reconditioning of the dredged sediment to remove salt prior to disposal at Twitchell Island would eliminate the potential for contaminant migration as leachate. In addition, dredging should be conducted in a manner that minimizes the amount of estuarine water transported with the sediment to Twitchell Island for disposal. Collection and treatment of leachate at the 7th Street disposal site is recommended to reduce the overall contaminant flux in leachate from the disposal operation. Control of suspended solids in effluent and surface runoff at each disposal site is recommended. A mixing zone of 10 to 1 will be required to dilute any contaminant in effluent and surface runoff waters to meet imposed water quality limitation standards.

Management of plant colonization is recommended to minimize cadmium migration into the herbivore food chain and to deter colonization by birds and mammals. If Oakland sediments are used to supplement levee stability and plant growth occurs on these sediments, plant uptake of cadmium will potentially exceed acceptable levels for agricultural production of leafy vegetables and small grains such as wheat. Therefore, plant growth on the levees should be restricted to nonagricultural production. The levees should be planted with grass species that minimize cadmium uptake such as red fescue. Monitoring of the plant and animal communities that establish at the Twitchell Island disposal site is recommended to verify minimization of contaminant migration into herbivore food chains.

## REFERENCES

- American Public Health Association. 1976. "Standard Methods for the Examination of Water and Wastewater," 14th ed., Washington, DC.
- Barr, A. J., Goodnight, J. H., Sall, J. P., and Helwig, J. T. 1976. "A Users Guide to SAS 76," SAS Institute, Inc., Raleigh, NC.
- Brannon, J. M., Myers, T. E. and Price, C. B. 1990. "Factors Affecting the Behavior of Metals in Leachate," Environmental Effects of Dredging Technical Note EEDP-02-13, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Brannon, J. M., Plumb, R. H., Jr., and Smith, I. 1978. "Long-Term Release of Contaminants from Dredged Material," Technical Report D-78-49, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- CEC (Commission of the European Communities). 1984. "Directive 79/831, Annex V, Part C: Methods for the Determination of Ecotoxicity-Level 1, Earthworms-Artificial Soil" (Rev. 5), DG XI/128/82, Brussels, Belgium.
- Day, P. R. 1956. "Report of the Committee on Physical Analyses (1954-1955)," Soil Sci. Soc. Am. Proc., Vol 20, pp 167-169.
- Environmental Laboratory. 1987. "Disposal Alternatives for PCB-Contaminated Sediments from Indiana Harbor, Indiana," Miscellaneous Paper EL-87-9, 2 vols, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- European Community. 1974. "Tot Vastelling van de Maximale Gehalten aan Ongewenste Stoffen en Produkten in Diervoeders," Publ. blad EEG., Vol 17 (L38), pp 31-36.
- Folsom, B. L., Jr., and Houck, M. H. 1990. "A Computerized Procedure for Predicting Plant Uptake of Heavy Metals from Contaminated Freshwater Dredged Material," Environmental Effects of Dredging Technical Note EEDP-04-12, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Folsom, B. L., Jr., Davis, B. E., and Houghton, N. J. 1988. "Heavy Metal Uptake by Agronomic Crops and *Cyperus esculentus* Grown on Oxidized and Reduced Soils Contaminated with Metal-Mining Wastes," Technical Note EEDP-02-06, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Folsom, B. L., Jr., Lee, C. R., and Bates, D. J. 1981. "Influence of Disposal Environment on Availability and Plant Uptake of Heavy Metals in Dredged Material," Technical Report EL-81-12, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Folsom, B. L., Jr., Pennington, J. C., Teeter, C. L., Barton, M. R., and Bright, J. A. 1988a. "Effects of Soil pH and Treatment Level on Persistence and Plant Uptake of 2,4,6-Trinitrotoluene," Technical Report EL-88-22, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Folsom, B. L., Jr., Skogerboe, J. G., Palermo, M. R., Simmers, J. W., Pranger, S. A., and Shafer, R. A. 1988b. "Synthesis of the Results of the Field Verification Program Upland Disposal Alternative," Technical Report D-88-7, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Francingues, N. R., Palermo, M. R., Lee, C. R., and Peddicord, R. K. 1985. "Management Strategy for Disposal of Dredged Material: Test Protocols and Contaminant Control Measures," Miscellaneous Paper D-85-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

- Francois, Roger, and Weber, J. H. 1988. "Speciation of Methyltin and Butyltin Compounds in Eelgrass (*Zostera marina* L.) Leaf Tissue from the Great Bay Estuary (NH)," Marine Chemistry, Vol 25, pp 279-289.
- Gal, J. Y., and Bouche, M. B. 1988. "Correlation of Lethal Concentrations of Heavy Metals with Tissue Levels of Earthworms," Technical Report, Laboratoire de Zoecologie du Sol and Laboratoire de Chime Analytique, University of Montpellier, France.
- Kay, S. H., Scholten, M. C. Th., and Bowmer, C. T. 1988. "Mobility of Soil Contaminants in an Ecosystem of Trees Growing on Dredged Material--The Broekpolder (Rotterdam, The Netherlands)," Technical Report R88/488, Technology for Society Division (MT) of Netherlands Organization for Applied Scientific Research (TNO), Delft, Netherlands.
- Klute, A. 1965. "Water Capacity," Methods of Soil Analysis, C. A. Black, ed., Monograph No. 9, American Society of Agronomy, Madison, WI, pp 273-278.
- Krivolutski, D., Turganinova, V., and Mikhaltsova, Z. 1982. "Earthworms as Bioindicators of Radioactive Soil Pollution," Pedobiologia, Vol 23, pp 263-265.
- Krone, C. A., Brown, D. W., Burrows, D. G., Bogar, R. G., Chan, S. L., and Varanasi, U. 1989. "A Method for Analysis of Butyltin Species and Measurement of Butyltins in Sediment and English Sole Livers from Puget Sound," Marine Environmental Research, Vol 27, pp 1-18.
- Lee, C. R., and Skogerboe, J. G. 1984. "Restoration of Pyritic Soils and the Quantification of Erosion Control," Miscellaneous Paper EL-84-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Lee, C. R., Folsom, B. L., Jr., and Bates, D. J. 1983. "Prediction of Plant Uptake of Toxic Metals Using a Modified DTPA Soil Extractant," The Science of the Total Environment, No. 28, pp 191-202.
- Lee, C. R., Folsom, B. L., Jr., and Engler, R. M. 1982. "Availability and Uptake of Heavy Metals from Contaminated Dredged Material Placed in Flooded and Upland Disposal Environments," Environment International, No. 7, pp 65-71.
- Lee, C. R., et al. 1978. "Prediction of Heavy Metal Uptake by Marsh Plants Based on Chemical Extraction of Heavy Metals from Dredged Material," Technical Report D-78-6, US Army Engineer Waterways Experiment Station, Vicksburg, Ms.
- Lee, C. R., et al. 1991. "General Decisionmaking Framework for Management of Dredged Material--Example Application to Commencement Bay, Washington," Miscellaneous Paper D-91-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Linden, O. 1987. "The scope of the organotin issue in Scandinavia," International Organotin Symposium, Marine Technology Society, IEEE Ocean Engineering Society, pp 1320-1323.
- Maguire, R. J., and Tkacz, R. J. 1985. "Degradation of the Tri-n-butyltin Species in Water and Sediment from Toronto Harbor," Journal of Agriculture and Food Chemistry, Vol 33, pp 947-953.
- McLane, M. R., Stickel, L., and Newsom, J. 1971. "Organochlorine Pesticide Residues in Woodcock, Soils, and Earthworms in Louisiana," Pesticides Monitoring Journal, Vol 3, pp 248-250.

- Marquenie, J. M., Simmers, J. W., and Kay, S. H. 1987. "Bioaccumulation of Metals and Organic Contaminants at the Times Beach Confined Disposal Site, Buffalo, New York," Miscellaneous Paper EL-87-6, US Army Engineer Waterways Experiment Station, Environmental Laboratory, Vicksburg, MS.
- Morin, J., Cluff, D. B., and Powers, W. R. 1970. "Realistic Rainfall Simulation for Field Investigation," paper presented at 51st Meeting of American Geophysical Union, Washington, DC.
- Morin, J., Goldberg, D., and Seginer, I. 1967. "A Rainfall Simulator with a Rotating Disk," Transactions of the American Society of Agricultural Engineers, Vol 10, No. 1, pp 74-79.
- Myers, T. E., and Brannon, J. M. 1988. "New Bedford Harbor Superfund Project, Acushnet River Estuary Engineering Feasibility Study of Dredging and Dredged Material Disposal Alternatives; Report 5, Evaluation of Leachate Quality," Technical Report EL-88-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Nielson, K. K., and Sanders, R. W. 1983. "Multielement Analysis of Unweighed Biological and Geological Samples Using Backscatter and Fundamental Parameters," Adv. X-Ray Anal., Vol 26, pp 385-390.
- Palermo, M. R. 1985. "Interim Guidance for Predicting the Quality of Effluent Discharged from Dredged Material Disposal Areas," Environmental Effects of Dredging Operations Technical Notes EEDP-04-1 through 4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Palermo, M. R., et al. 1989. "Evaluation of Dredged Material Disposal Alternatives for US Navy Homeport at Everett, Washington," Technical Report EL-89-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Patrick, W. H., Jr. 1958. "Modification of Method of Particle Size Analysis," Soil Sci. Soc. Am. Proc., Vol 22, pp 366-267.
- \_\_\_\_\_. 1990 (May). "A Field and Laboratory Investigation of Toxic Heavy Metal Release from Oakland Inner Harbor Sediments," Port of Oakland, Oakland, CA.
- Rhett, G., Adema, D. M. M., Roza, P., and Henzen, R. 1989. "Rate and Effects of PCB Accumulation on *Eisenia foetida*," Technical Report R89/339, Technology for Society Division (MT) of Netherlands Organization for Applied Scientific Research (TNO), Delft, Netherlands.
- Rhoades, J. D. 1982. "Soluble Salts," Methods of Soil Analysis, C. A. Black, ed., Monograph No. 9., American Society of Agronomy, Madison, WI, pp 167-179.
- Rice, C. D., Espourteille, F. A., and Huggett, R. J. 1987. "Analysis of Tributyltin in Estuarine Sediments and Oyster Tissue, *Crassostrea virginica*," Applied Organometal Chemistry, Vol 1, pp 541-544.
- SAS-Institute Inc. 1988. SAS/STAT User's Guide, Release 6.03 Edition, Cary, NC.
- Seligman, P. F., Valkirs, A. O., and Lee, R. F. 1986. "Degradation of Tributyltin in San Diego Bay, California, Waters," Environmental Science and Technology, Vol 20, pp 1229-1235.
- Short, J. W., and Sharp, J. L. 1989. "Tributyltin in Bay Mussels (*Mytilus edulis*) of the Pacific Coast of the United States," Environmental Science and Technology, Vol 23, pp 740-743.

- Simmers, J. W., Apfelbaum, S. A., and Bryniarski, L. F. 1990. "Assessment of Avian Botulism Control Pilot Project at Dike 14 Confined Dredged Material Disposal Facility, Cleveland, Ohio," Miscellaneous Paper EL-90-23, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Skogerboe, John G., et al. 1987. "Prediction of Surface Runoff Water Quality from Black Rock Harbor Dredged Material Placed in an Upland Disposal Site," Miscellaneous Paper D-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Sokal, R. R., and Rohlf, F. J. 1981. Biometry, The Principles and Practice of Statistics in Biological Research, 2nd ed., W. H. Freeman and Company, San Francisco, CA.
- Stafford, E. A., Simmers, J. W., Rhett, R. G., and Brown, C. P. 1991. "Interim Report: Collation and Interpretation of Data for Times Beach Confined Disposal Facility, Buffalo, New York," Miscellaneous Paper D-91-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Unger, M. A., MacIntyre, W. G., Greaves, J., and Huggett, R. J. 1986. "GC Determination of Butyltins in Natural Waters by Flame Photometric Detection of Hexyl Derivatives with Mass Spectrometric Confirmation," Chemosphere, Vol 15, No. 4, pp 461-470.
- US Army Corps of Engineers. 1987. "Confined Disposal of Dredged Material," Engineer Manual 1110-2-5027, Washington, DC.
- US Environmental Protection Agency. 1984. "EPA Part VIII 40 CFR, Part 136, Methods 608 and 625," Washington, DC.
- \_\_\_\_\_. 1986. "Test Methods for Evaluating Solid Wastes, SW-846 Methods 8080 and 8270," 3rd ed, Office of Solid Waste and Emergency Response, Washington, DC.
- \_\_\_\_\_. 1987. "United States Environmental Protection Agency Office of Water Regulations and Standards Criteria and Standards Division, Update #2 to 'Quality Criteria for Water 1986,'" Criteria and Standards Division, Washington, DC.
- van Driel, W., Smilde, K. W., and van Luit, B. 1985. "Comparison of the Heavy-Metal Uptake of *Cyperus esculentus* and of Agronomic Plants Grown on Contaminated Dutch Sediments, Miscellaneous Paper D-83-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.
- Winer, B. J. 1971. Statistical Principles in Experimental Design, McGraw-Hill Book Company, New York.
- Westerdahl, H. E., and Skogerboe, J. G. 1982. "Realistic Rainfall and Watershed Response Simulations for Assessing Water Quality Impacts of Land Use Management," Modeling Components of Hydrologic Cycle, International Symposium on Rainfall-Runoff Modeling, Mississippi State University, Mississippi State, MS., pp 87-104.
- World Health Organization. 1972. "Evaluation of Certain Food Additives, Mercury, Lead, and Cadmium," Technical Report Series 505, Rome, Italy.

APPENDIX A: SEDIMENT COLLECTION AND CHEMICAL CHARACTERIZATION



DRAFT CRUISE REPORT

ECOLOGICAL EVALUATION OF PROPOSED DISCHARGE  
OF DREDGED MATERIAL FROM OAKLAND HARBOR  
INTO OCEAN WATERS (WES/UPLANDS PROGRAM)

J. A. Ward  
J. C. Coley  
L. D. Antrim

Battelle/Marine Sciences Laboratory  
Sequim, Washington

January 1989

Submitted to  
U.S. Army Corps of Engineers  
San Francisco, California 94105

Battelle, Pacific Northwest Laboratories  
Richland, Washington 99352

### ACKNOWLEDGMENTS

We would like to express our appreciation to Brian Walls of the USACE; to personnel from Manson Pacific including Ruben Virgil, Keith Orr, and George Baker; and to John Corona and Ted Rose from Land and Sea Surveyors, Inc.

### Enclosures

- 1 - Chain of Custody Sheets
- 2 - Participating Personnel
- 3 - Sediment Chemical Characterization

## 1.0 INTRODUCTION

The Battelle Marine Sciences Laboratory (MSL) is currently conducting bioassay, bioaccumulation, and analytical chemistry tests on sediments proposed for dredging from the Inner and Outer Harbors at Oakland California. The purpose of these tests is to assist the U.S. Army Corps of Engineers (USACE) and the Environmental Protection Agency (EPA) in evaluating the acceptability of the sediments for unconfined open-water disposal. This testing is mandated by Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972 (Public Law 92-532) and is directed according to criteria published in the Federal Register (1977)(a). Battelle has participated in four of these projects: Bulk Sediment Analysis (January 1988), Oakland Harbor -38 Foot Project (March 1988), Oakland Inner Harbor, Phase I (June 1988), and Oakland Outer Harbor, Phase II (October 1988).

As a result of these tests, the dredged materials committee overseeing these projects has decided that some of the sediments in the vicinity of the Oakland Harbor turning basin may require upland disposal. Studies are currently underway which evaluate contaminant transport associated with the dredged material disposed at upland locations. For one study, the Battelle Marine Sciences Laboratory of Pacific Northwest Laboratory was requested by USACE to supervise the collection and transport of sediment from the Oakland Harbor turning basin (Figure 1) and two upland sites near Oakland Harbor (Figures 2 and 3) to the USACE Waterways Experiment Station (WES) in Vicksburg, Mississippi. These sediments will be used by WES during one of the uplands studies.

(a) Federal Register, 1977. "Ocean Dumping. Final Revisions of Regulation." Part VI, Vol. 42, No. 7.

The objectives of the field collections included:

- The collection of approximately 1650 gal of sediment (6246 L) from predetermined locations at the edge of the turning basin of Oakland Harbor, California, to a maximum depth of -44 ft MLLW
- The collection of 55 gal (208 L) of sediment from each of two upland sites in the vicinity of Oakland Harbor, California
- The containment and storage of the collected sediments in epoxy-coated 55 gal drums at a temperature of 4°C
- The transportation via refrigerated truck of the sediment to USACE's Waterways Experiment Station in Vicksburg, Mississippi

## 2.0 FIELD COLLECTIONS

Sample collections were made between December 13 and December 16, 1988. Sediments were collected at 20 stations along the edges of the Oakland Harbor turning basin on December 13, 14, and 16, 1988 (Figure 1, Table 1), and from upland sites on December 15 (Figures 2 and 3). Sediments from Oakland Harbor were collected to a project depth of -44 ft MLLW. Surface soil samples were collected at two upland sites to a depth of about 2 ft. The upland sites sampled included Twitchell Island near the junction of the San Joaquin and Sacramento Rivers, and the 7th Street Terminal near Oakland.

At the turning basin sites, the upper portion (mudline to -38 ft MLLW) and lower portion (-38 ft to -44 ft MLLW) of sediment cores from each station were placed in separate 55 gal drums. At the upland sites, material collected was placed in separate 55 gal drums. These drums were factory-coated with a clear phenolic epoxy made by Interchem, Inc. This epoxy is considered non-toxic and non-contaminating by the USFDA. The drums were used to contain all sediments collected during this project. Sediment storage temperatures of 4°C were maintained by placing the drums in a refrigerated truck located near the Oakland Harbor collection area. This truck received sample drums on a daily basis.

## 2.1 OAKLAND HARBOR TURNING BASIN

For this project, a split core sampling device (Figure 4) designed by Battelle MSL and fabricated by Manson Pacific, Inc., was used to sample the Oakland Harbor turning basin stations. This coring tool is 40 ft long and has an inner diameter of 12 in. (30.5 cm). The lower 20 ft of the core sampling device is "split" into two longitudinal halves which unbolt and open to allow removal of the cored sediment. The sampler end of the core is equipped with one-way "flapper" doors which prevent the contents of the core from spilling out when it is lifted from the bottom (Figure 4). In locations where Merritt Sand was anticipated or encountered, a 6-ton electrical vibratory hammer was installed on the core sampler. This vibrator head was also used successfully in the USACE -42 Foot Phase II of the Oakland Outer Harbor project and aids in penetration of highly compacted sediments such as Merritt Sand. The core sampler was generally able to sample to the project depth of -44 ft MLLW, except when Merritt Sand formations caused the device to reach a point of refusal, even after employing the vibratory hammer. Prior to use, the inner surface of the core sampler was coated with a non-toxic epoxy material (Engard 480 H.S.), which peeled off during the first coring attempt due to friction associated with the sediment. The core was used "as is" for the remainder of the cruise, and the sediment touching the sides of the core was discarded.

This coring apparatus was operated from the platform barge, Andrew, using an 80 ft supporting crane. A tugboat maneuvered the barge to specific coring sites within the Harbor. A staging area for mobilization, demobilization, and equipment storage was established at the Manson Pacific facilities near Oakland Harbor.

Navigational support during the coring operation was provided by Land and Sea Surveyors, Inc. of Ventura, California. Coring stations were located using a Geodimeter laser/range azimuth positioning system, with navigational survey-control points located at the Union Pacific Railroad Yard, Monument Chan, and the Crowley Marine Dock in the vicinity of Todd Shipyard. The California State Coordinates (Zone III) for these points are N478193.85, E1471745.84, N474967.18, E1479560.29, and N475303.82, E1483103.14, respectively. Before coring commenced, the navigators surveyed the station reference coordinates, deployed station buoys, and determined station depths

with a lead-line deployed from a skiff. The uncorrected depth determined in this manner was recorded in the station logs of Land and Sea Surveys. Depth corrections were made during the actual coring by measuring the water level with respect to a known tidal benchmark (Monument Chan, for instance, is 10.39 feet above MLLW) and applying the appropriate correction factor to the depth recorded on the coring barge at that time. This method eliminates the use of a tide table, thereby reducing error when applying general tide table calculations to MLLW depth. Tide tables were consulted during the coring operation, however, and compared to MLLW water depths in the coring area as a second check on the corrected MLLW depths radioed to the derrick barge by Land and Sea survey personnel. Verified MLLW depths were recorded in Battelle field logs, as well as uncorrected depths, and the total core length needed to penetrate to the required depth. Once the Andrew was anchored in position suing spuds, and MLLW depths were verified, the station buoy offset was determined and radioed to the crane operator, so that the coring device could be positioned correctly. The coring device was lowered to the bottom and coring depth was measured using calibrated marks on the core barrel. When the coring device had penetrated to -44 ft or as deep as possible, the core was retrieved, and the core sample was processed.

After a core was collected, the core sampler was lifted onto the barge, positioned on the deck, and opened for sample retrieval. Core sample lengths were measured, and the core was divided into upper and lower sections. The section of the core from sediment surface to -38 ft MLLW was called the upper sample; the section from -38 ft to -44 ft MLLW was called the lower sample. Upper and lower samples were transferred to individual 55 gal drums using epoxy coated shovels. Between samples, the core sampler was washed with seawater and scrubbed to remove sediment, as necessary. At the end of each day, the drums were transferred to the refrigerated truck.

A total of 20 stations were occupied along the edges of the turning basin (Table 1) resulting in 31 drums of sediment from this area. Due to poor sampler penetration, we were unable to collect good cores at station OI-TS-4, and were able to collect only upper portions (mudline to -38 ft MLLW) at stations OI-TS-3, TS-3A, TS-7, and OI-TS-2. At stations SS-8 and SS-9, sediments from -38 to -44 ft MLLW were collected only, for the water depths approached -38 ft MLLW. At 13 stations, both upper and lower portions were

collected. Where Merritt Sand prevented penetration to full project depth, replicate cores were necessary until enough material was collected to fill the 55 gal drum.

## 2.2 UPLAND SAMPLING

Sampling locations at upland sites were determined by USACE and actual sampling points were picked by Battelle personnel after visual inspection of the sites. The locations of the two sites are depicted in Figures 2 and 3. Upland sediment collections were made by digging manually with epoxy-coated shovels. The surface debris was cleared from the site and soil was shoveled to fill a 55 gal drum.

At the 7<sup>th</sup> St. Oakland site (Figure 2), the sediment sample was taken from an area 38 in. in diameter and 18 in. in depth at the approximate center of the site. Vertical characterization of the site showed the upper 2 in. composed of bark and gravel, the 2 to 8 in. segment composed of fine sand and gravel, the 8 to 15-in. segment composed of sand, gravel, rocks, and black soil; and the 15 to 18-in portion composed of fine soil with rocks.

The Twitchell Island site (Figure 3) was located in the center of a field along the southwest dike of the island. The surface of the site was covered with grass which was cleared from a small area. A sample of sandy loam was taken starting at 6 in. depth from an area 36 in. in diameter and extending to a depth of 24 in..

## 2.3 SAMPLE TRANSPORT

At the end of each day, sediment samples collected and stored in the 55 gal drums were placed in a refrigerated truck located at the Manson Pacific facilities and the storage temperature was maintained at 4°C. On Friday, December 16, all sampling was completed and a total of 33 55 gal drums were secured aboard the truck, including 31 drums from the Oakland Harbor turning Basin and one drum from each of the two upland sites. On Saturday, December 17, 1988, the truck left the Manson facilities enroute to the USACE Waterways Experiment Station (WES) at Vicksburg, Mississippi. The collected material and MSL Chain of Custody sheets (Enclosure 1) were delivered to Mr. Richard Lee of WES on December 21, 1988.

TABLE 1. Summary of Sediment Collection in Oakland Harbor

<u>Station</u>	<u>Core Number</u>	<u>Sampling Date</u> (MM-DD-YY)	<u>California State</u> <u>Zone III Coordinates</u>		<u>Water Depth</u> (MLW ft)	<u>Required Core Length (ft)</u>	<u>Collected Core Length (ft)</u>	<u>Comments</u>
			<u>(X)</u>	<u>East (Y)</u>				
TS-1-A	1	12-13-88	1,482,956	475,397	30.0	14.0	11.5	Soft, dark upper mud, lower Merritt Sand
TS-1-A	2	12-13-88	1,482,956	475,397	30.0	14.0	11.0	Top of sample is undisturbed mud. Merritt Sand present in lower sample
01-TS-1	1	12-13-88	1,482,977	475,418	29.0	15.0	14.0	Mud and sand present. One-way flapper broke
01-TS-1	2	12-13-88	1,482,977	475,418	29.0	15.0	15.0	Merritt Sand present, interfered with core catcher
01-TS-3	1	12-13-88	1,483,528	475,460	25.7	18.3	13.0	Merritt Sand at 10 ft below mudline. Cored to -38 MLW (upper) only
TS-3-A	1	12-13-88	1,483,547	475,481	27.2	16.0	10.3	Collected to -38 ft MLW only and composited with 01-TS-3 (approx 10 ft away). Surface to 5 ft: soft mud; Lower 5 ft: Merritt Sand
01-TS-4	1	12-13-88	1,483,290	475,285	20.3	23.7	10.0	Surface to 1.5 ft: soft mud; next 1.0 ft: gray clay Core and station rejected



TABLE 1. Summary of Sediment Collection in Oakland Harbor, Continued

Station	Core Number	Sampling Date (MM-DD-YY)	California State Zone III Coordinates		Water Depth (MLW ft)	Required Core Length (ft)	Collected Core Length (ft)	Comments
			(X) East	(Y) North				
00-TS-5A	1	12-13-88	1,483,745	475,425	30.9	13.1	6.0	One-way flapper malfunction, much of core lost. Coarse slag and soft mud present
00-TS-5A	2	12-13-88	1,483,745	475,425	30.9	13.1	13.3	Surface to 10 ft: soft black mud/slag; 10-13 ft: gray clay and Merritt Sand
01-TS-5	1	12-13-88	1,483,656	475,360	29.9	14.1	14.0	Surface to 6 ft: soft mud; 6-14 ft: gravel and slag
01-TS-5	2	12-13-88	1,483,656	475,360	29.9	14.1	14.0	Upper portion: soft mud; Lower portion: black gravel
01-SS-3	1	12-14-88	1,483,268	476,224	28.8	15.2	15.6	Upper portion: soft, black mud; lower portion: mixed mud and sand; bottom 1 ft: clean sand. Only snail to sample
01-SS-3	2	12-14-88	1,483,268	476,224	28.8	15.2	15.6	Black mud and sand
01-SS-3A	1	12-14-88	1,483,306	476,273	33.2	10.8	11.0	Upper portion: soft mud, lower portion: mud and sand. High organic content. Located 60 ft SW of 01-SS-3
01-SS-3A	2	12-14-88	1,483,306	476,273	36.0	8.0	8.0	Upper portion: black mud; Lower portion: sand
01-SS-3A	3	12-14-88	1,483,306	476,273	33.2	10.8	11.0	Steep slope to bottom in this area. Sediments vary greatly

TABLE 1. Summary of Sediment Collection in Oakland Harbor, Continued

Station	Core Number	Sampling Date (MM-DD-YY)	California State Zone III Coordinates		Water Depth (MLW ft)	Required Core Length (ft)	Collected Core Length (ft)	Comments
			(X) East	(Y) North				
01-SS-1	1	12-14-88	1,483,070	476,350	28.8	16.2	14.7	Upper portion: soft, black mud and clay; Lower portion: black clay and sand grading to clean clay then sand
01-SS-1	2	12-14-88	1,483,070	476,350	28.8	16.2	16.0	
01-SS-2	1	12-14-88	1,483,006	476,180	29.5	14.5	12.0	Upper portion: soft mud; Lower portion: clay and sand
01-SS-2	2	12-14-88	1,483,006	476,180	29.5	14.5	10.5	Surface to 8 ft: soft mud; 8 ft to 10.5 ft: grey clay and mud
01-SS-2	3	12-14-88	1,483,006	476,180	29.5	14.5	13.5	Fine clay/sand in lower portion made coring difficult
TS-6	1	12-14-88	1,483,859	475,426	26.2	17.8	13.0	Surface to 10 ft: soft mud; 10 ft to 13 ft: Merritt Sand
TS-6	2	12-14-88	1,483,859	475,426	26.2	17.8	13.2	Lower portion: Merritt Sand
TS-7	1	12-14-88	1,483,602	475,363	21.9	22.1	14.7	Surface to 10 ft: soft mud 10 ft to 13 ft: Merritt Sand. Upper sample only
TS-7	2	12-14-88	1,483,602	475,363	21.9	22.1	14.0	Upper sample only
SS-6A	1	12-14-88	No Data	No Data	No Data	No Data	No Data	Sounding at site indicates water too deep to give upper sample

TABLE 1. Summary of Sediment Collection in Oakland Harbor, Continued

Station	Core Number	Sampling Date (MM-DD-YY)	California State Zone III Coordinates		Water Depth (MLW ft)	Required Core Length (ft)	Collected Core Length (ft)	Comments
			(X) East	(Y) North				
SS-6	1	12-14-88	1,483,568	476,348	28.7	15.3	13.2	Upper portion: soft mud; Lower portion: sand. Oil visible in sediment. Hit piling on first attempt
SS-6	2	12-14-88	1,483,568	476,348	28.7	15.3	13.8	Black, oily sediment. Steep Slope to bottom. Lots of debris on sediment surface
01-SS-4	1	12-16-88	1,483,520	476,245	32.0	12.0	10.9	Upper surface: soft mud. Merritt Sand at 10 ft. Epoxy coating peeled off inside of barrel. Samples contain epoxy chips
01-SS-4	2	12-16-88	1,483,520	476,245	32.0	12.0	None	Penetration through Merritt Sand broke core hinges. Repairs necessary
SS-7	1	12-16-88	1,483,647	476,377	36.0	8.0	8.0	Surface to 4 ft: soft mud; 4 ft to 8 ft: sand
SS-7	2	12-16-88	1,483,647	476,377	36.0	8.0	8.6	Soft black mud at surface; sand and grey clay at lower layers
SS-7	3	12-16-88	1,483,647	476,377	36.0	8.0	8.6	Same as above
SS-8	1	12-16-88	1,483,766	476,385	38.8	5.2	8.0	Water too deep for upper sample. Soft mud, sand and clay

TABLE 1. Summary of Sediment Collection in Oakland Harbor, Continued

Station	Core Number	Sampling Date (MM-DD-YY)	California State Zone III Coordinates		Water Depth (MLLW ft)	Required Core Length (ft)	Collected Core Length (ft)	Comments
			(X) East	(Y) North				
SS-8	2	12-16-88	1,483,786	476,385	38.8	5.2	8.3	Same as SS-8
SS-9	1	12-16-88	1,483,803	476,346	37.1	6.9	7.0	No upper sample. Surface 1 ft: soft mud; 1 ft to 2.5 ft: sand; 2.5 ft to 7 ft: hard, grey clay
SS-9	2	12-16-88	1,483,803	476,346	37.1	6.9	6.8	Same as above
SS-10	1	12-16-88	1,482,964	476,216	34.0	10.0	10.0	Surface to 4 ft: soft oily mud; 4 ft to 10 ft: mud and clay
SS-10	2	12-16-88	1,482,964	476,216	34.0	10.0	<del>10.0</del>	Same as above
01-TS-2	1	12-16-88	1,483,270	475,450	30.0	14.0	10.0	Surface to 2 ft: soft, black mud with oil; 2 ft to 3.5 ft: clay and mud; lower 4.5 ft: Merritt Sand
01-TS-2	2	12-16-88	1,483,270	475,450	30.0	14.0	8.0	Same as above

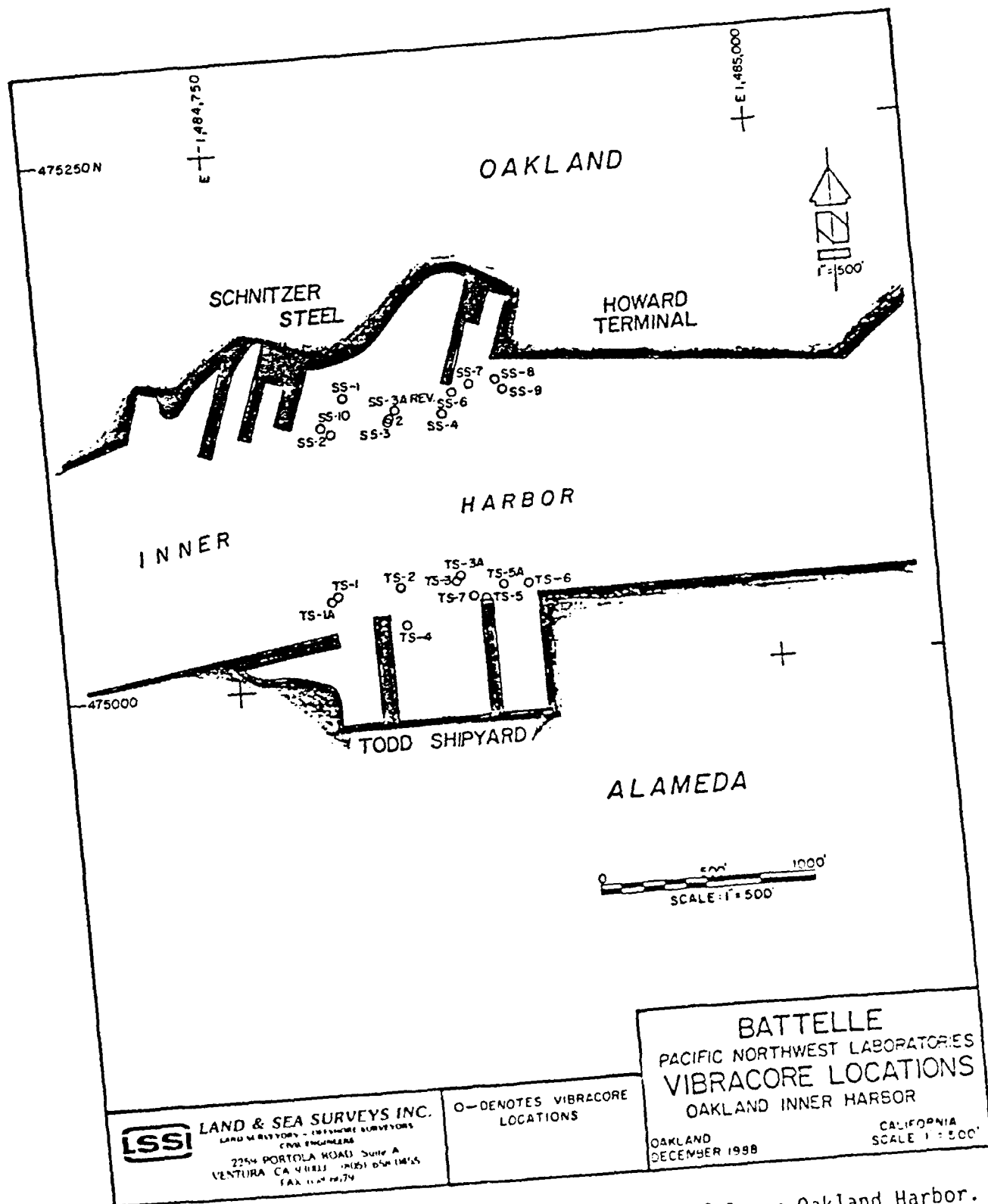


FIGURE 1. Sampling Locations in Turning Basin of Inner Oakland Harbor.



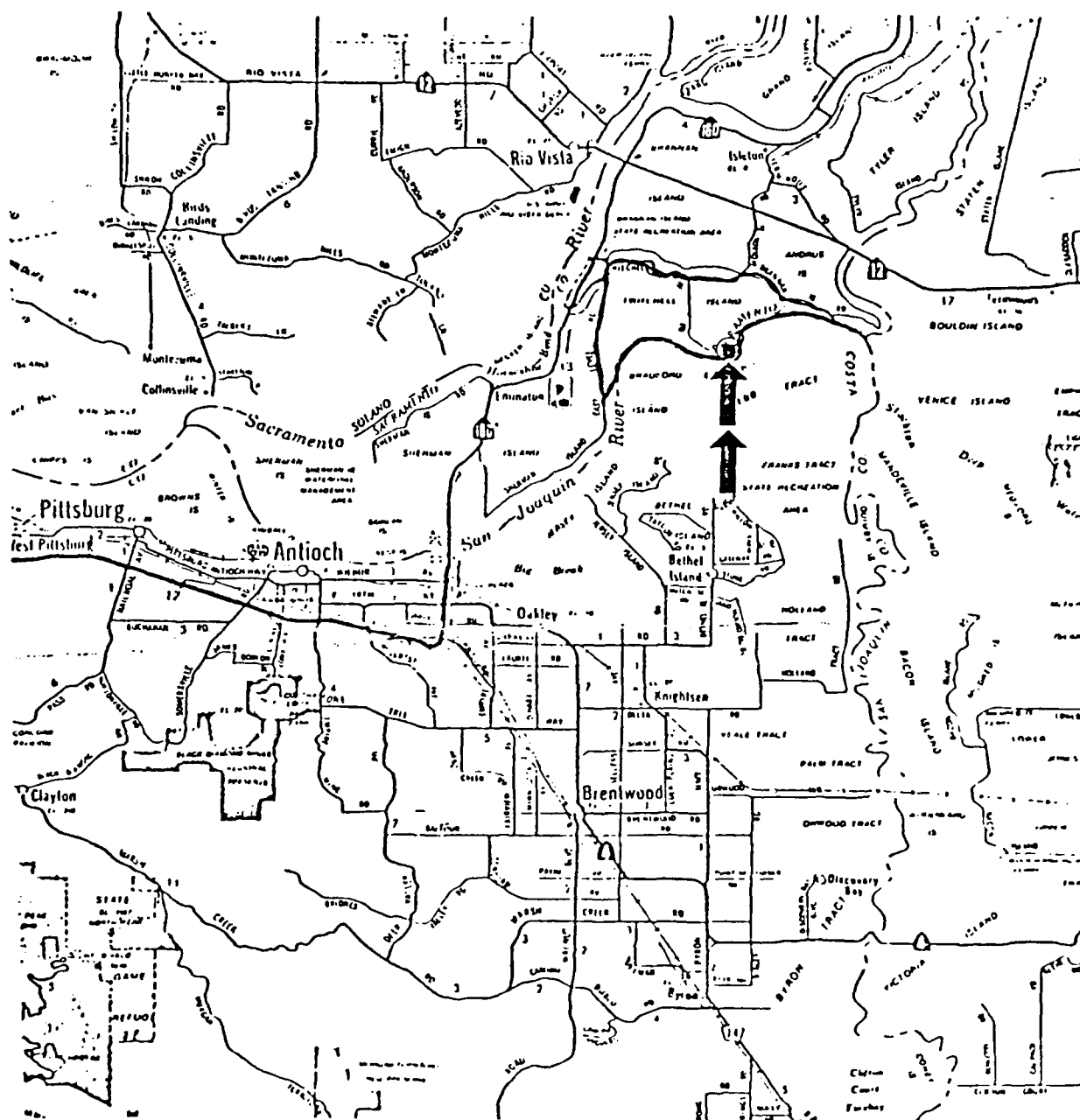


FIGURE 3. Sampling Location of the Twitchell Island Upland Site.

USACE SAN FRANCISCO

WES UPLANDS PROJECT

CHAIN OF CUSTODY

Sample Number	Sample Type	Released By / Date	Accepted By / Date
CI-SS-1 UPPER	SEDIMENT	James E. Long 12-16-88	
OI-SS-1 LOWER		James E. Long 12-16	
OI-SS-2 UPPER		James E. Long 12-16	
OI-SS-2 LOWER		James E. Long 12-16	
OI-SS-3 UPPER		James E. Long 12-16	
OI-SS-3 LOWER		James E. Long 12-16	
OI-TS-1 UPPER		James E. Long 12-16	
OI-TS-1 LOWER		James E. Long 12-16	
OI-TS-3 UPPER		James E. Long 12-16	
OI-TS-5 UPPER		James E. Long 12-16	
OI-TS-5 LOWER		James E. Long 12-16	
OO-TS-5A UPPER		James E. Long 12-16	
OO-TS-5A LOWER		James E. Long 12-16	
OI-SS-3A UPPER		James E. Long 12-16	
OI-SS-3A LOWER		James E. Long 12-16	
<del>NEW SS-1A UPPER</del>		<del>James E. Long 12-16</del>	
NEW TS-1A UPPER		James E. Long 12-16	
NEW TS-1A LOWER		James E. Long 12-16	
NEW TS-6 UPPER		James E. Long 12-16	
NEW TS-6 LOWER		James E. Long 12-16	
NEW TS-7 UPPER		James E. Long 12-16	
NEW SS-6 UPPER		James E. Long 12-16	
NEW SS-6 LOWER		James E. Long 12-16	
NEW SS-7 UPPER		James E. Long 12-16	
NEW SS-7 LOWER		James E. Long 12-16	

Please sign and return the original to: — Jeff Ward

Battelle MSL  
439 W. Sequim Bay Rd  
Sequim, WA 98382  
206-683-4151

Enclosure 1



## USACE SAN FRANCISCO

## WES UPLANDS PROJECT

## CHAIN OF CUSTODY

Sample Number	Sample Type	Released By / Date	Accepted By / Date
SS-9 LOWER	SEDIMENT	James Ely 12-16-88	
SS-4 UPPER		James Ely 12-16-88	
SS-4 LOWER		James Ely 12-16-88	
SS-10 UPPER		James Ely 12-16	
SS-10 LOWER		James Ely 12-16	
TS-2 UPPER		James Ely 12-16	
#1 7th ST		James Ely 12-16-88	
#1A Twitchel Island		James Ely 12-16-88	

TOTAL - 33 DRUMS 55 GAL EACH

James Ely 12-16-88

Please sign and return the original to:

Jeff Ward  
 Battelle MSL  
 439 W. Sequim Bay Rd  
 Sequim, WA 98382  
 206-683-4151

## Participating Personnel

### Battelle

Mr. James C. Coley, Cruise Chief  
Mr. James S. Young

### Manson Pacific

Ruben Virgil  
Keith Orr  
George Baker

### Land and Sea Surveys, Inc.

John Corona  
Ted Rose  
Field Crew

Enclosure 2

**CONCENTRATIONS OF ORGANOTINS AND METALS IN OAKLAND HARBOR SEDIMENTS  
ORGANOTIN AND METAL SAMPLES (COLLECTED IN FEBRUARY, 1989)**

SAMPLE ID	Butyltin (ug/kg as Sn dry weight)*				Metals (ug/g dry weight)									
	Tri	Di	Mono	Total	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Sb	Zn
S1-1 Upper 1	309	55	8	372	0.751	8.9	0.87	336	91	1.041	116	80	1.94	225
S1-2 Upper 1	149	54	12	215	—	10.1	0.97	316	98	0.816	117	74	—	214
S1-3 Upper 1	89	31	5	125	—	13.0	1.19	311	100	1.115	122	78	—	231
S1-4 Upper 1	603	173	25	801	—	8.6	0.81	322	121	1.076	111	105	—	203
S1-1 Lower 1	10	4	1	15	0.25	5.4	0.26	571	35	0.457	66	20	0.56	74
S1-2 Lower 1	4	3	1	7	—	4.2	0.67	605	51	0.720	69	37	—	96
S1-3 Lower 1	3	1	1	4	—	6.5	0.27	653	52	0.726	70	18	—	76
S1-4 Lower 1	41	7	2	50	—	5.5	0.26	514	25	0.242	66	16	—	68
S1-1A Twitchell Is	<1	<1	<1	<3	0.138	14.7	0.46	129	41	0.214	73	13	1.2	96
S1-1a 7th St.	<1	1	1	<2	0.615	24.5	0.56	348	563	0.346	65	120	5.83	303
Blank, SQ and NBS Data														
Blank	<0.6	0.4	<0.5	<2	0.02	—	<0.01	—	—	0.042	—	—	0.08	—
SQ-1	46.0	<0.9	<0.8	<48	—	—	—	—	—	—	—	—	—	—
S1-1 NOAA	30.0	—	—	30	—	—	—	—	—	—	—	—	—	—
NBS-1646	—	—	—	—	0.084	9.4	0.39	77	18.6	0.074	33.9	28.1	0.24	133.3
Certified	—	—	—	—	NC	11.6	0.36	76	18	0.063	32	28.2	NC	138
Value	—	—	—	—	NC	±1.3	±0.07	±3	±3	±0.012	±3	±1.8	NC	±6

\* = To convert the Sn concentrations to butyltin cations, multiply Sn value by 2.44 for TBT, 1.96 for DBT and 1.48 for MBT.

— = Data not available.

NC = Not certified.

# OAKLAND HARBOR PESTICIDE/PCBs IN SEDIMENT SAMPLES

Parameter	ug/Kg dry weight				Method Blank
	S1-1 Lower 1	S1-1 Upper 1	S1-1A Twitchell Is	S1-1 7th St.	
Alpha-BHC	1.0 U	1.5 U	1.0 U	1.0 U	1.0 U
Beta-BHC	1.0 U	1.5 U	1.0 U	1.0 U	1.0 U
Delta-BHC	1.0 U	1.5 U	1.0 U	1.0 U	1.0 U
Gamma-BHC (Lindane)	1.0 U	1.5 U	1.0 U	1.0 U	1.0 U
Heptachlor	1.0 U	1.5 U	1.0 U	1.0 U	1.0 U
Aldrin	1.0 U	1.5 U	1.0 U	1.0 U	1.0 U
Heptachlor Epoxide	1.0 U	1.5 U	1.0 U	1.0 U	1.0 U
Endosulfan I	1.0 U	1.5 U	1.0 U	1.0 U	1.0 U
Dieldrin	1.5 U	3.0 U	1.5 U	1.6 U	1.5 U
4,4'-DDE	2.0 U	3.5 U	2.6 U	2.0 U	1.5 U
Endrin	1.5 U	3.0 U	1.5 U	1.5 U	1.5 U
Endosulfan II	1.5 U	3.0 U	1.5 U	1.6 U	1.5 U
4,4'-DDD	3.0 U	4.5 U	3.0 U	3.0 U	3.0 U
Endosulfan Sulfate	3.0 U	4.5 U	3.0 U	3.0 U	3.0 U
4,4'-DDT	2.0 U	5.0 U	5.8 U	11	2.0 U
Methoxychlor	4.0 U	6.0 U	4.0 U	4.0 U	4.0 U
Endrin Ketone	1.5 U	2.5 U	1.5 U	1.5 U	1.5 U
Gamma-Chlordane	2.0 U	2.5 U	1.0 U	2.2	1.0 U
Alpha-Chlordane	1.0 U	1.5 U	1.0 U	1.1	1.0 U
Toxaphene	150 U	225 U	150 U	150 U	150 U
Aroclor-1242/1016	20 U	30 U	20 U	20 U	20 U
Aroclor-1248	20 U	30 U	20 U	20 U	20 U
Aroclor-1254	59	120	20 U	42	20 U
Aroclor-1260	20 U	30 U	20 U	20 U	20 U
% Surrogate Recovery:					
Dibutylchlorodate	93%	75%	81%	90%	76%

U = Indicates compound was analyzed for but not detected at the given detection limit.

# OAKLAND HARBOR VOLATILES IN SEDIMENT SAMPLES

	ug/Kg dry weight				
Parameter	S1-1 Lower 1	S1-1 Upper 1	S1-1A Twitchell Is	S1-1 7th St.	Method Blank
Chloromethane	4.2 U	4.1 U	51.0 U	3.4 U	3.8 U
Bromomethane	3.5 U	3.4 U	42.0 U	2.7 U	3.1 U
Vinyl Chloride	2.2 U	2.2 U	27.0 U	1.8 U	2.0 U
Chloroethane	3.7 U	3.6 U	45.0 U	2.9 U	3.3 U
Methylene Chloride	31.0 B	120.0 B	760.0 B	180.0 B	3.3 J
Acetone	32.0	70.0 U	93.0	6.1 U	6.9 U
Carbon Disulfide	1.3 U	1.3 U	16.0 U	1.1 U	1.2 U
1,1-Dichloroethene	0.8 U	0.8 U	9.5 U	0.6 U	0.7 U
1,1-Dichloroethane	0.7 U	0.7 U	8.1 U	0.5 U	0.6 U
1,2-Dichloroethene (total)	0.9 U	0.9 U	11.0 U	0.7 U	0.8 U
Chloroform	1.2 U	1.2 U	15.0 U	1.0 U	1.1 U
1,2-Dichloroethane	0.6 U	0.5 U	6.8 U	0.4 U	0.5 U
2-Butanone	6.9 U	6.8 U	84.0 U	5.5 U	6.2 U
1,1,1-Trichloroethane	0.7 U	0.7 U	8.1 U	0.5 U	0.6 U
Carbon Tetrachloride	1.0 U	1.0 U	12.0 U	0.8 U	0.9 U
Vinyl Acetate	3.5 U	3.4 U	42.0 U	2.7 U	3.1 U
Bromodichloromethane	0.3 U	0.3 U	4.1 U	0.3 U	0.3 U
1,2-Dichloropropane	0.8 U	0.8 U	9.5 U	0.6 U	0.7 U
cis-1,3-Dichloropropene	2.0 U	2.0 U	24.0 U	1.6 U	1.8 U
Trichloroethene	0.7 U	0.7 U	8.1 U	0.5 U	0.6 U
Dibromochloromethane	0.8 U	0.8 U	9.5 U	0.6 U	0.7 U
1,1,2-Trichloroethane	0.8 U	0.8 U	9.5 U	0.6 U	0.7 U
Benzene	1.1 U	1.1 U	14.0 U	0.9 U	1.0 U
Trans-1,3-Dichloropropene	2.1 U	2.1 U	26.0 U	1.7 U	1.9 U
2-Chloroethylvinylether	3.0 U	2.9 U	37.0 U	2.4 U	2.7 U
Bromoform	2.8 U	2.7 U	34.0 U	2.2 U	2.5 U
4-Methyl-2-Pentanone	3.9 U	3.8 U	47.0 U	3.1 U	3.5 U
2-Hexanone	3.6 U	3.5 U	43.0 U	2.8 U	3.2 U
Tetrachloroethene	0.6 U	0.5 U	6.8 U	0.4 U	0.5 U
1,1,2,2-Tetrachloroethane	3.0 U	2.9 U	37.0 U	2.4 U	2.7 U
Toluene	0.9 U	0.9 U	11.0 U	0.7 U	0.8 U
Chlorobenzene	1.0 U	1.0 U	12.0 U	0.8 U	0.9 U
Ethylbenzene	6.0	3.5	11.0 U	0.7 U	0.8 U
Styrene	1.2 U	1.2 U	15.0 U	1.0 U	1.1 U
Total Xylenes	44.0	22.0	24.0 U	1.7 J	1.8 U
% Surrogate Recoveries:					
d8-Toluene	98.9%	100.0%	102.0%	106.0%	102.0%
Bromofluorobenzene	92.9%	90.3%	92.8%	88.5%	93.1%
d4-1,2-Dichloroethane	97.8%	99.2%	97.8%	96.3%	92.6%

U = Indicates compound was analyzed for but not detected at the given detection limit.

B = This flag is used when the analyte is found in the blank as well as a sample.

Indicates possible/probable blank contamination.

J = Indicates an estimated value when result is less than specified detection limit.

# OAKLAND HARBOR SEMIVOLATILES IN SEDIMENT SAMPLES

Parameter	<i>ug/Kg dry weight</i>				Method Blank
	S1-1 Lower 1	S1-1 Upper 1	S1-1A Twitchell Is	S1-1 7th St.	
Phenol	22 U	34 U	21 U	19 U	20 U
bis(2-Chloroethyl)Ether	22 U	34 U	21 U	19 U	20 U
2-Chlorophenol	22 U	34 U	21 U	19 U	20 U
1,3-Dichlorobenzene	22 U	34 U	21 U	19 U	20 U
1,4-Dichlorobenzene	22 U	34 U	21 U	19 U	20 U
Benzyl Alcohol	110 U	170 U	100 U	100 U	100 U
1,2-Dichlorobenzene	22 U	34 U	21 U	19 U	20 U
2-Methylphenol	22 U	34 U	21 U	19 U	20 U
bis(2-ChloroIsopropyl)Ether	22 U	34 U	21 U	19 U	20 U
4-Methylphenol	22 U	34 U	21 U	19 U	20 U
N-Nitroso-Di-n-Propylamine	22 U	34 U	21 U	19 U	20 U
Hexachloroethane	40 U	70 U	40 U	40 U	40 U
Nitrobenzene	22 U	34 U	21 U	19 U	20 U
Isophorone	22 U	34 U	21 U	19 U	20 U
2-Nitrophenol	110 U	170 U	100 U	100 U	100 U
2,4-Dimethylphenol	40 U	70 U	40 U	40 U	40 U
Benzoic Acid	220 U	340 U	210 U	190 U	200 U
bis(2-Chloroethoxy)Methane	22 U	34 U	21 U	19 U	20 U
2,4-Dichlorophenol	70 U	100 U	60 U	60 U	60 U
1,2,4-Trichlorobenzene	22 U	34 U	21 U	19 U	20 U
Naphthalene	58	140	21 U	15 J	20 U
4-Chloroaniline	70 U	100 U	60 U	60 U	60 U
Hexachlorobutadiene	40 U	70 U	40 U	40 U	40 U
4-Chloro-3-Methylphenol	40 U	70 U	40 U	40 U	40 U
2-Methylnaphthalene	10 J	16 J	21 U	9 J	20 U
Hexachlorocyclopentadiene	110 U	170 U	100 U	100 U	100 U
2,4,6-Trichlorophenol	110 U	170 U	100 U	100 U	100 U
2,4,5-Trichlorophenol	110 U	170 U	100 U	100 U	100 U
2-Chloronaphthalene	22 U	34 U	21 U	19 U	20 U
2-Nitroaniline	110 U	170 U	100 U	100 U	100 U
Dimethyl Phthalate	22 U	34 U	21 U	19 U	20 U
Acenaphthylene	17 J	73	21 U	19 U	20 U
3-Nitroaniline	110 U	170 U	100 U	100 U	100 U
Acenaphthene	210	610	21 U	16 J	20 U
2,4-Dinitrophenol	220 U	340 U	210 U	190 J	200 U
4-Nitrophenol	110 U	170 U	100 U	100 U	100 U
Dibenzofuran	14 J	31 J	21 U	9 J	20 U
2,4-Dinitrotoluene	110 U	170 U	100 U	100 U	100 U
2,6-Dinitrotoluene	110 U	170 U	100 U	100 U	100 U
Diethylphthalate	22 U	34 U	21 U	19 U	20 U
4-Chlorophenyl-phenylether	22 U	34 U	21 U	19 U	20 U
Fluorene	95	150	21 U	8 J	20 U
4-Nitroaniline	110 U	170 U	100 U	100 U	100 U
4,6-Dinitro-2-Methylphenol	220 U	340 U	210 U	190 U	200 U
N-Nitrosodiphenylamine (1)	22 U	34 U	21 U	19 U	20 U
4-Bromophenyl-phenylether	22 U	34 U	21 U	19 U	20 U
Hexachlorobenzene	22 U	34 U	21 U	19 U	20 U

# OAKLAND HARBOR SEMIVOLATILES IN SEDIMENT SAMPLES

Parameter	ug/Kg dry weight				Method Blank
	S1-1 Lower 1	S1-1 Upper 1	S1-1A Twitchell Is	S1-1 7th St.	
Pentachlorophenol	110 U	170 U	100 U	100 U	100 U
Phenanthrene	1100	2600	48	120	20 U
Anthracene	300	850	21 U	30	20 U
Di-n-Butylphthalate	22 U	34 U	21 U	19 U	20 U
Fluoranthene	1200	3400	260	180	20 U
Pyrene	1200	3600	320	150	20 U
Butylbenzylphthalate	22 U	34 U	21 U	19 U	20 U
3,3-Dichlorobenzidine	110 U	170 U	100 U	100 U	100 U
Benzo(a)Anthracene	330	1100	66	60	20 U
bis(2-Ethylhexyl)Phthalate	59	410	21 U	200	20 U
Chrysene	460	1600	120	130	20 U
Di-n-Octyl Phthalate	28 M	34 U	21 U	19 U	20 U
Benzo(b),(k) Fluoranthene	750	3000	250	300	20 U
Benzo(a)Pyrene	560	2200	180	100	20 U
Indeno(1,2,3-cd)Pyrene	350	1300	180	92	20 U
Dibenz(a,h)Anthracene	64	210	15 J	30	20 U
Benzo(g,h,i)Perylene	350	1400	210	71	20 U

## % Base/Neutral Surrogate Recoveries:

d-5-Nitrobenzene	78.4%	81.5%	75.0%	85.8%	90.2%
2-Fluorobiphenyl	72.6%	73.6%	70.0%	74.3%	79.0%
d-14-p-Terphenyl	68.3%	71.5%	68.5%	69.2%	80.5%

## % Acid Surrogate Recoveries:

d5-Phenol	63.3%	68.2%	72.8%	79.4%	79.1%
2-Fluorophenol	57.4%	62.8%	62.1%	70.1%	72.8%
2,4,6-Tribromophenol	80.4%	88.8%	83.1%	87.6%	79.7%

(1) Cannot be separated from diphenylamine.

U = Indicates compound was analyzed for but not detected at the given detection limit.

J = Indicates an estimated value when result is less than specified detection limit.

M = Indicates an estimated value of analyte found and confirmed by analyst but with low spectral match parameters.

APPENDIX B: EFFLUENT TEST



Waterways Experiment Station  
Oakland Harbor Project  
Metal Samples (Collected in February, 1989)

Sample Number	Treatment	Metals (µg/L)						
		As	Cd	Cr	Cu	Hg	Pb	Zn
D-Upper 1	Dissolved	6.51	0.073	4.06	0.77	0.008	16.8	7.5
D-Upper 2	Dissolved	7.25	0.093	4.25	0.9	<0.002	16.8	7.5
D-Upper 3	Dissolved	5.28	0.125	3.7	1.01	<0.002	14.3	10
T-Upper 1	Total	9.3	0.074	3.89	3.67	0.021	26.2	15
T-Upper 2	Total	9.1	0.037	3.36	4.5	0.017	17.7	17.5
T-Upper 3	Total	6.24	0.062	4.28	2.12	<0.002	14.3	10
D-Lower 1	Dissolved	1.65	0.161	3.52	0.48	<0.002	18.0	10
D-Lower 2	Dissolved	1.55	0.096	3.07	0.5	<0.002	17.6	15
D-Lower 3	Dissolved	1.57	0.05	3.53	0.69	<0.002	20.4	10
T-Lower 1	Total	2.11	0.128	4.81	1.06	<0.002	24.5	10
T-Lower 2	Total	1.71	0.023	3.57	1.11	<0.002	17.2	10
T-Lower 3	Total	1.29	0.243	4.05	1.55	<0.002	19.2	10

Blank, Site Water and Standard Reference Material (SLRS-1, 1643-a and CASS-1)

Sample Number	Treatment	Metals (µg/L)						
		As	Cd	Cr	Cu	Hg	Pb	Zn
Blank	-	0.03	0.001	0.051	< 0.02	-	0.41	5
Site Water	Total	1.71	0.121	3.16	5.15	<0.002	23.3	17.5
SRM SLRS-1		-	-	0.31	-	-	-	-
SLRS-1 Certified Value		-	-	0.36 ±0.04	-	-	-	-
SRM 1643-a		-	-	-	-	-	-	67.5
1643-a Certified Value		-	-	-	-	-	-	72.0 ±4.0
SRM CASS-1		1.18	0.034	-	0.33	-	0.278	-
CASS-1 Certified Value		1.04 ±0.07	0.026 ±0.005	-	0.291 ±0.027	-	0.251 ±0.027	-

- = Data Not Available

Waterways Experiment Station  
Oakland Harbor Project  
Organotin Samples (Collected in February, 1989)

<u>Sample Number</u>	<u>Treatment</u>	<u>Butyltin (ng/L as Sn)*</u>		
		<u>Tri</u>	<u>Di</u>	<u>Mono</u>
D-Upper 1	Dissolved	4	6	< 1
D-Upper 2	Dissolved	7	4	< 2
D-Upper 3	Dissolved	6	3	< 2
T-Upper 1	Total	20	46	3
T-Upper 2	Total	14	8	< 1
T-Upper 3	Total	10	32	2
D-Lower 1	Dissolved	3	< 3	< 2
D-Lower 2	Dissolved	2	30	2
D-Lower 3	Dissolved	3	51	2
T-Lower 1	Total	6	< 3	< 2
T-Lower 2	Total	6	< 2	< 2
T-Lower 3	Total	7	4	4

Blank and Site Water Data

<u>Sample Number</u>	<u>Treatment</u>	<u>Butyltin (ng/L as Sn)*</u>		
		<u>Tri</u>	<u>Di</u>	<u>Mono</u>
Procedural Blank	-	2	< 1	< 1
Site Water	Total	< 1	1	< 1

\* To convert the Sn concentrations to butyltin cations, multiply Sn value by 2.44 for TBT, 1.96 for DBT and 1.48 for MBT.

APPENDIX C: SURFACE RUNOFF TEST

TABLE C-1, CONTINUED  
OAKLAND HARBOR SURFACE RUNOFF WATER QUALITY DATA

OBS	SEDIMENT	STAGE	TYPE	REP	AS	CD
1	Upper	DRY	UNFILT	1.00	2.10	0.33
2	Upper	DRY	UNFILT	2.00	1.80	0.33
3	Upper	DRY	UNFILT	3.00	1.80	0.14
4	Lower	DRY	UNFILT	1.00	1.20	1.18
5	Lower	DRY	UNFILT	2.00	< 1.05	1.04
6	Lower	DRY	UNFILT	3.00	< 1.05	1.79
7	Upper	WET	UNFILT	1.00	119.00	22.00
8	Upper	WET	UNFILT	2.00	33.50	7.33
9	Upper	WET	UNFILT	3.00	14.60	4.03
10	Upper	WET	UNFILT	4.00	29.50	4.40
11	Lower	WET	UNFILT	1.00	34.80	8.80
12	Lower	WET	UNFILT	2.00	13.60	2.93
13	Lower	WET	UNFILT	3.00	9.98	1.83
14	Upper	DRY	FILT	1.00	< 1.05	0.47
15	Upper	DRY	FILT	2.00	< 1.05	0.47
16	Upper	DRY	FILT	3.00	< 1.05	0.14

OBS	CR	CU	HG	PB	ZN	TRIBUTYL TIN
1	1.34	35.40	0.0298	30.60	87.00	0.0560
2	1.50	46.70	0.0275	51.00	147.00	0.0740
3	1.50	65.60	0.2940	47.80	150.00	0.0340
4	1.96	43.80	0.0062	47.30	463.00	0.0210
5	2.03	69.00	0.0342	66.80	530.00	0.0200
6	1.25	57.40	0.0262	49.60	250.00	0.0220
7	1643.00	1417.00	0.0100	1185.00	6548.00	0.5600
8	489.00	500.00	0.0030	416.00	1809.00	0.3860
9	337.80	292.00	0.0010	273.00	737.00	0.0860
10	337.80	338.00	0.0020	329.00	744.00	0.2200
11	1408.00	583.00	0.0040	529.00	1348.00	0.0390
12	497.00	125.00	0.0030	221.00	483.00	0.0140
13	312.00	292.00	0.0020	308.00	292.00	0.0100
14	0.28	10.50	0.0214	0.93	53.00	0.0140
15	0.28	10.50	0.0214	0.93	43.00	0.0084
16	0.09	4.20	0.0130	< 0.80	47.00	0.0850

TABLE C-1, CONTINUED			
OAKLAND HARBOR SURFACE RUNOFF WATER QUALITY DATA			
OBS	DIBUTYL TIN	MONOBUTYL TIN	TOTAL BUTYL TIN
1	0.0180	0.0040	0.0780
2	0.0300	0.0190	0.1230
3	0.0190	0.0170	0.0700
4	0.0150	< 0.0043	0.0360
5	0.0120	0.0075	0.0395
6	0.0120	< 0.0049	0.0340
7	0.1260	0.0040	0.6900
8	0.0940	0.0020	0.4820
9	0.0360	0.0040	0.1260
10	0.0850	0.0030	0.3080
11	0.0190	0.0020	0.0600
12	0.0130	0.0070	0.0340
13	0.0080	0.0020	0.0200
14	0.0070	< 0.0047	0.0210
15	0.0130	0.0130	0.0340
16	0.0380	0.0030	0.1260

TABLE C-1, CONTINUED

OBS	SEDIMENT	OAKLAND HARBOR STAGE	SURFACE RUNOFF TYPE	WATER QUALITY REP	DATA AS	CD
17	Lower	DRY	FILT	1.00	< 1.05	0.42
18	Lower	DRY	FILT	2.00	< 1.05	0.47
19	Lower	DRY	FILT	3.00	< 1.05	0.38
20	Upper	WET	FILT	1.00	2.08	0.45
21	Upper	WET	FILT	2.00	2.27	0.10
22	Upper	WET	FILT	3.00	1.61	0.28
23	Upper	WET	FILT	4.00	2.07	0.12
24	Lower	WET	FILT	1.00	1.20	0.29
25	Lower	WET	FILT	2.00	1.63	0.26
26	Lower	WET	FILT	3.00	2.89	0.10

OBS	CR	CU	HG	PB	ZN	TRIBUTYL TIN
17	0.05	4.20	0.0121	0.93	67.00	0.0130
18	0.09	3.40	0.0116	1.86	60.00	0.0120
19	0.46	4.00	0.0153	1.86	80.00	0.0110
20	1.45	8.95	0.3490	1.09	64.50	0.0090
21	0.90	5.68	0.0300	1.09	27.19	0.0040
22	0.55	6.60	0.0100	0.63	24.20	0.0050
23	0.68	3.77	0.0090	0.63	24.80	0.0080
24	1.54	2.36	0.1770	0.73	41.80	0.0030
25	0.58	8.49	0.0980	0.63	13.10	0.0060
26	1.28	5.66	0.0270	1.81	81.40	0.0020

OBS	DIBUTYL TIN	MONOBUTYL TIN	TOTAL BUTYL TIN
17	0.0210	0.0045	0.0390
18	0.0110	< 0.0030	0.0230
19	0.0110	< 0.0062	0.0220
20	0.0060	0.0030	0.0180
21	0.0600	0.0030	0.0670
22	0.0090	0.0030	0.0170
23	0.0030	0.0010	0.0120
24	0.1150	0.0060	0.1240
25	0.0170	0.0040	0.0270
26	0.0040	0.0020	0.0080

TABLE C-2  
PAH SURFACE RUNOFF WATER QUALITY DATA

OBS	PARAMETER	REP1	REP2
1	NAPHTHALENE	2.56	1.12
2	2 METHYL NAPHTHALENE	0.79	0.16
3	ACENAPHTHALENE	1.77	0.33
4	ACENAPHTHENE	2.41	0.46
5	FLUORENE	1.30	1.41
6	PHENANTHRENE	17.95	2.85
7	ANTHRACENE	7.31	1.36

OBS	REP3	REP4	RO WATER
1	1.22	0.51	0.66
2	0.18	0.10	-0.02
3	0.20	0.25	-0.02
4	0.46	0.33	-0.02
5	1.75	0.41	-0.02
6	2.88	3.21	-0.02
7	0.92	1.13	-0.02

OBS	PARAMETER	REP1	REP2
8	FLUORANTHENE	44.66	7.86
9	PYRENE	77.73	14.78
10	BENZO (A) ANTHRACENE	5.29	2.59
11	CHRYSENE	15.22	4.79
12	BENZO (B) FLUORANTHENE	37.94	5.64
13	BENZO (K) FLUORANTHENE	11.28	4.58
14	BENZO (A) PYRENE	28.86	7.06

OBS	REP3	REP4	RO WATER
8	6.67	8.00	-0.01
9	10.63	13.33	-0.02
10	2.21	2.61	-0.02
11	3.83	4.53	-0.02
12	4.40	6.81	-0.02
13	3.35	1.97	-0.02
14	5.90	6.33	-0.02

TABLE C-2  
PAH SURFACE RUNOFF WATER QUALITY DATA

OBS	PARAMETER	REP1	REP2
15	INDEMO (1,2,3,4) PYRENE	18.85	5.05
16	DIBENZO (A,L) ANTHRACENE	2.79	0.84
17	BENZO (G,H,I) PERYLENE	7.49	6.88
18	TOTAL PAH	273.93	67.76
OBS	REP3	REP4	RO WATER
15	4.53	4.17	-0.02
16	0.66	0.53	-0.02
17	6.12	5.62	-0.02
18	55.90	59.85	0.36



TABLE C-3  
SURFACE RUNOFF QUALITY, HEAVY METAL QA/QC

	<u>As</u>	<u>Cd</u>	<u>Cr</u>	<u>Cu</u>	<u>Hg</u>	<u>Pb</u>	<u>Zn</u>
WES Blank #1	< 0.19	< 1.27	< 8.34	< 0.41	< 0.001	8.22	4.63
WES Blank #2	< 0.19	< 1.27	8.34	1.24	< 0.001	2.18	30.9
Lab Blank Total Conc.	< 0.19	0.17	0.42	0.42	< 0.001	0.87	2.4
Lab Blank Filtered Conc.	< 0.19	0.113	0.051	1.89	< 0.001	0.73	1.67
WES Duplicat Set 1	33.5	7.33	489	600	0.003	416	1809
Total Conc.	29.5	4.4	338	333	0.002	329	744
WES Duplicate Set 2	2.27	< 0.098	0.9	5.66	0.030	1.09	27.19
Filtered Conc.	2.07	0.118	0.68	3.77	0.009	< 0.63	24.8
Lab Duplicate Set	14.6	4.03	202	292	0.001	273	737
Total Conc.	16.3	4.03	270	292	0.002	303	712
SRM SLRS-1-CF	--	--	0.81	--	--	--	1.66
SLRS-1 CERT.	--	--	0.36	--	--	--	1.34
VALUE	--	--	± 0.04	--	--	--	± 1.67
SRM SLRS-1	--	--	0.32	--	--	--	--
SLRS-1 CERT.	--	--	0.36	--	--	--	--
VALUE	--	--	± 0.04	--	--	--	--
SRM 1643-a-CF	--	10.9	--	17.5	--	20.6	--
SRM 1643-a-CU	--	10.3	18.5	19.4	< 0.001	26.0	68.7
1643-a CERT.	--	10.0	17.0	18.0	NC	27.0	72.0
VALUE	--	± 1.0	± 2.0	± 2.0	--	± 1.0	--
SRM 1643-a	82	10.3	--	19.0	--	27.6	73
1643-a CERT.	76	10	--	18.0	--	27	72
VALUE	± 7	± 1	--	± 2	--	± 1	± 4
SRM CASS-1-CU	1.18	--	--	--	--	--	--
CASS-1 CERT.	1.04	--	--	--	--	--	--
VALUE	± 0.07	--	--	--	--	--	--
SRM 1641-b	--	--	--	--	0.0275	--	--
1641-b CERT.	--	--	--	--	0.0299	--	--
VALUE	--	--	--	--	± 0.0006	--	--

TABLE C-4  
THE WES SURFACE RUNOFF QUALITY, BUTYL TIN QA/QC

	<u>Tri</u>	<u>Di</u>	<u>Mono</u>
WES Blank #1	< 2.44	< 1.96	< 1.48
WES Blank #2	4.88	< 3.92	< 2.96
LAB BLANK	4.88	< 1.96	< 1.48
WES Duplicat Set 1	942	184	2.96
Total Conc.	537	167	4.44
WES Duplicate Set 2	9.76	118	4.44
Filtered Conc.	19.5	5.88	< 1.48

<u>SAMPLE</u>	<u>PROPYL TIN % RECOVERY</u>
UD1-FCT	36
UD2-TCT	27
UD3-TCT	34
LD1-TCT	44
LD2-TCT	39
LD2-FCT	29
LD3-TCT	49
LD3-FCT	40

---

APPENDIX D: LEACHATE TEST

APPENDIX D: EXAMPLE HELP MODEL PRINTOUT FOR CDF SCENARIO D,  
MEMBRANE LINER AND LEACHATE COLLECTION

\*\*\*\*\*  
\*\*\*\*\*  
OAKLAND HARBOR  
LOWER ON UPPER - W/ LEACHATE CONTROLS - 500,000 CU YD  
14 DECEMBER 1989  
\*\*\*\*\*  
\*\*\*\*\*

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	115.20 INCHES
POROSITY	=	0.4300 VOL/VOL
FIELD CAPACITY	=	0.1900 VOL/VOL
WILTING POINT	=	0.0850 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000012699999 CM/SEC

LAYER 2

VERTICAL PERCOLATION LAYER

THICKNESS	=	28.80 INCHES
POROSITY	=	0.7000 VOL/VOL
FIELD CAPACITY	=	0.3100 VOL/VOL
WILTING POINT	=	0.1870 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7000 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000000580000 CM/SEC

LAYER 3

LATERAL DRAINAGE LAYER

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4370 VOL/VOL
FIELD CAPACITY	=	0.0620 VOL/VOL
WILTING POINT	=	0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0437 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.005799999926 CM/SEC
SLOPE	=	0.01 PERCENT
DRAINAGE LENGTH	=	600.0 FEET

LAYER 4

BARRIER SOIL LINER WITH FLEXIBLE MEMBRANE LINER

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4310 VOL/VOL
FIELD CAPACITY	=	0.3660 VOL/VOL
WILTING POINT	=	0.2800 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4310 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.000000100000 CM/SEC
LINER LEAKAGE FRACTION	=	0.01000000

GENERAL SIMULATION DATA

-----

SCS RUNOFF CURVE NUMBER	=	88.00
TOTAL AREA OF COVER	=	1125000. SQ FT
EVAPORATIVE ZONE DEPTH	=	16.00 INCHES

UPPER LIMIT VEG. STORAGE	=	6.8800 INCHES
INITIAL VEG. STORAGE	=	6.8800 INCHES
INITIAL SNOW WATER CONTENT	=	0.0000 INCHES
INITIAL TOTAL WATER STORAGE IN SOIL AND WASTE LAYERS	=	75.3924 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

#### CLIMATOLOGICAL DATA

SYNTHETIC RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND  
SOLAR RADIATION FOR SAN FRANCISCO CALIFORNIA

MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	125
END OF GROWING SEASON (JULIAN DATE)	=	301

#### NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-----	-----	-----	-----	-----	-----
48.50	51.60	52.80	54.80	57.80	60.80
62.20	63.00	63.90	60.60	54.50	49.20

\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 1

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	15.58	1460625.	100.00
RUNOFF	4.595	430823.	29.50
EVAPOTRANSPIRATION	10.548	988897.	67.70
LATERAL DRAINAGE FROM LAYER 3	0.9797	91843.	6.29
PERCOLATION FROM LAYER 4	0.0603	5650.	0.39
CHANGE IN WATER STORAGE	-0.604	-56588.	-3.87
SOIL WATER AT START OF YEAR	75.39	7068037.	
SOIL WATER AT END OF YEAR	74.79	7011449.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	1.	0.00

\*\*\*\*\*

\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 2

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	20.91	1960313.	100.00
RUNOFF	6.169	578305.	29.50
EVAPOTRANSPIRATION	11.681	1095108.	55.86
LATERAL DRAINAGE FROM LAYER 3	2.7262	255586.	13.04
PERCOLATION FROM LAYER 4	0.1432	13420.	0.68
CHANGE IN WATER STORAGE	0.191	17894.	0.91
SOIL WATER AT START OF YEAR	74.79	7011449.	
SOIL WATER AT END OF YEAR	74.98	7029342.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

\*\*\*\*\*

\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 3

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	14.36	1346250.	100.00
RUNOFF	2.772	259847.	19.30
EVAPOTRANSPIRATION	10.473	981871.	72.93
LATERAL DRAINAGE FROM LAYER 3	2.7538	258165.	19.18
PERCOLATION FROM LAYER 4	0.1444	13541.	1.01
CHANGE IN WATER STORAGE	-1.783	-167175.	-12.42
SOIL WATER AT START OF YEAR	74.98	7029342.	
SOIL WATER AT END OF YEAR	73.20	6862167.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	1.	0.00

\*\*\*\*\*



\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 4

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	14.76	1383750.	100.00
RUNOFF	3.457	324080.	23.42
EVAPOTRANSPIRATION	9.996	937112.	67.72
LATERAL DRAINAGE FROM LAYER 3	2.6872	251928.	18.21
PERCOLATION FROM LAYER 4	0.1414	13252.	0.96
CHANGE IN WATER STORAGE	-1.521	-142623.	-10.31
SOIL WATER AT START OF YEAR	73.20	6862167.	
SOIL WATER AT END OF YEAR	71.68	6719544.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

\*\*\*\*\*

\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 5

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	20.50	1921875.	100.00
RUNOFF	6.145	576100.	29.98
EVAPOTRANSPIRATION	14.174	1328856.	69.14
LATERAL DRAINAGE FROM LAYER 3	2.4506	229741.	11.95
PERCOLATION FROM LAYER 4	0.1302	12204.	0.63
CHANGE IN WATER STORAGE	-2.400	-225026.	-11.71
SOIL WATER AT START OF YEAR	71.68	6719544.	
SOIL WATER AT END OF YEAR	69.27	6494518.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

\*\*\*\*\*

\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 6			
	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	22.78	2135625.	100.00
RUNOFF	4.979	466822.	21.86
EVAPOTRANSPIRATION	15.047	1410658.	66.05
LATERAL DRAINAGE FROM LAYER 3	2.5156	235841.	11.04
PERCOLATION FROM LAYER 4	0.1332	12491.	0.58
CHANGE IN WATER STORAGE	0.105	9813.	0.46
SOIL WATER AT START OF YEAR	69.27	6494518.	
SOIL WATER AT END OF YEAR	69.38	6504332.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	-2.	0.00

\*\*\*\*\*

\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 7

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	23.67	2219062.	100.00
RUNOFF	7.564	709091.	31.95
EVAPOTRANSPIRATION	10.485	983015.	44.30
LATERAL DRAINAGE FROM LAYER 3	2.5201	236263.	10.65
PERCOLATION FROM LAYER 4	0.1335	12511.	0.56
CHANGE IN WATER STORAGE	2.967	278182.	12.54
SOIL WATER AT START OF YEAR	69.38	6504332.	
SOIL WATER AT END OF YEAR	72.35	6782513.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

\*\*\*\*\*

\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 8

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	19.84	1860001.	100.00
RUNOFF	6.684	626585.	33.69
EVAPOTRANSPIRATION	12.871	1206680.	64.88
LATERAL DRAINAGE FROM LAYER 3	2.5456	238650.	12.83
PERCOLATION FROM LAYER 4	0.1347	12627.	0.68
CHANGE IN WATER STORAGE	-2.395	-224541.	-12.07
SOIL WATER AT START OF YEAR	72.35	6782513.	
SOIL WATER AT END OF YEAR	69.95	6557972.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

\*\*\*\*\*

\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 9

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	15.71	1472812.	100.00
RUNOFF	2.371	222326.	15.10
EVAPOTRANSPIRATION	10.985	1029798.	69.92
LATERAL DRAINAGE FROM LAYER 3	2.3310	218528.	14.84
PERCOLATION FROM LAYER 4	0.1245	11674.	0.79
CHANGE IN WATER STORAGE	-0.101	-9514.	-0.65
SOIL WATER AT START OF YEAR	69.95	6557972.	
SOIL WATER AT END OF YEAR	69.85	6548459.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

\*\*\*\*\*

\*\*\*\*\*

ANNUAL TOTALS FOR YEAR 10

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	22.06	2068125.	100.00
RUNOFF	5.737	537872.	26.01
EVAPOTRANSPIRATION	16.263	1524680.	73.72
LATERAL DRAINAGE FROM LAYER 3	2.2483	210781.	10.19
PERCOLATION FROM LAYER 4	0.1206	11308.	0.55
CHANGE IN WATER STORAGE	-2.309	-216514.	-10.47
SOIL WATER AT START OF YEAR	69.85	6548459.	
SOIL WATER AT END OF YEAR	67.54	6331944.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

\*\*\*\*\*

\*\*\*\*\*

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 10

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
-----						
PRECIPITATION						
-----						
TOTALS	4.20 0.10	2.67 0.05	2.48 0.19	1.85 0.68	0.39 2.59	0.19 3.62
STD. DEVIATIONS	1.90 0.27	1.38 0.08	1.48 0.30	1.39 0.75	0.33 2.30	0.29 2.06
RUNOFF						
-----						
TOTALS	1.740 0.036	0.495 0.000	0.458 0.033	0.271 0.127	0.014 0.768	0.012 1.092
STD. DEVIATIONS	1.150 0.113	0.468 0.000	0.422 0.105	0.344 0.270	0.044 1.138	0.040 0.954
EVAPOTRANSPIRATION						
-----						
TOTALS	1.663 0.282	2.012 0.183	2.599 0.161	1.830 0.299	0.909 0.709	0.379 1.227
STD. DEVIATIONS	0.230 0.233	0.350 0.093	0.892 0.094	0.736 0.421	0.623 0.564	0.161 0.310
LATERAL DRAINAGE FROM LAYER 3						
-----						
TOTALS	0.1933 0.1956	0.1787 0.1946	0.1982 0.2075	0.1919 0.2133	0.1975 0.2048	0.1902 0.2103
STD. DEVIATIONS	0.0693 0.0653	0.0642 0.0632	0.0704 0.0150	0.0675 0.0163	0.0686 0.0156	0.0649 0.0160
PERCOLATION FROM LAYER 4						
-----						
TOTALS	0.0103 0.0105	0.0095 0.0104	0.0106 0.0110	0.0103 0.0113	0.0106 0.0109	0.0102 0.0112
STD. DEVIATIONS	0.0034 0.0031	0.0030 0.0030	0.0033 0.0007	0.0032 0.0008	0.0032 0.0007	0.0030 0.0008

\*\*\*\*\*



\*\*\*\*\*

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 10

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	19.02 ( 3.560)	1782844.	100.00
RUNOFF	5.047 ( 1.733)	473185.	26.54
EVAPOTRANSPIRATION	12.252 ( 2.216)	1148668.	64.43
LATERAL DRAINAGE FROM LAYER 3	2.3758 ( 0.5169)	222733.	12.49
PERCOLATION FROM LAYER 4	0.1266 ( 0.0245)	11868.	0.67
CHANGE IN WATER STORAGE	-0.785 ( 1.680)	-73609.	-4.13

\*\*\*\*\*

PEAK DAILY VALUES FOR YEARS 1 THROUGH 10

	(INCHES)	(CU. FT.)
PRECIPITATION	2.92	273750.0
RUNOFF	2.379	223050.6
LATERAL DRAINAGE FROM LAYER 3	0.0077	725.1
PERCOLATION FROM LAYER 4	0.0004	37.9
HEAD ON LAYER 4	130.8	
SNOW WATER	0.00	0.0
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4300	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0842	

\*\*\*\*\*

\*\*\*\*\*

FINAL WATER STORAGE AT END OF YEAR 10

LAYER	(INCHES)	(VOL/VOL)
1	36.96	0.3209
2	20.16	0.7000
3	5.24	0.4370
4	5.17	0.4310
SNOW WATER	0.00	

## APPENDIX E: PLANT TEST

Table E-1  
Butyltin in Washwater, ng/l

SED	WASH NO	REP	TETRA	TRI	DI	MONO	TOTAL	%REC
LOAK	1	1	<3.0	6.1	4.2	4.3	15	40
LOAK	1	2	<1.5	20	20	8.7	49	45
LOAK	1	3	<.09	10	6.7	3.8	21	39
LOAK	1	4	<1	8.1	7.6	5.4	21	36
UOAK	1	1	<3	21	21	21	63	48
UOAK	1	2	<2	16	15	<2.1	31	20
UOAK	1	3	<1.7	19	16	6.7	42	34
UOAK	1	4	<9	20	<13	12	32	50
LOAK	2	1	<11	<9.7	<16	<12	NA	40
LOAK	2	2	<12	<13	<18	<13	NA	70
LOAK	2	3	11	9.4	<16	<12	9	65
LOAK	2	4	SL	SL	SL	SL	SL	SL
UOAK	2	1	<6.4	16	8.6	14	39	39
UOAK	2	2	<2.2	13	7.1	11	31	39
UOAK	2	3	<3.9	15	11	18	44	34
UOAK	2	4	<2.8	17	9.6	13	40	34
LOAK	3	1	<4.1	13	9.6	22	45	32
LOAK	3	2	<3.3	12	107	4.1	123	48
LOAK	3	3	<5	18	19	<5.2	37	54
LOAK	3	4	<3.9	15	19	<4.1	34	40
UOAK	3	1	<2.9	28	22	6	56	47
UOAK	3	2	<4.7	22	12	5	39	38
UOAK	3	3	<3	23	28	5.1	56	54
UOAK	3	4	<3.8	28	21	4	53	52

No QA/QC, No standards

BLANK washwater 1	<15	56	46	<17	102	40
BLANK washwater 2	<3.2	12	5.9	5.5	23	35
BLANK washwater 3	<3.6	9.6	7.1	<3.8	17	49

SL Sample lost.  
NA Not applicable

Table E-2  
Butyltin in Sediment, ng/l

SED	WASH NO	REP	TETRA	TRI	DI	MONO	TOTAL	%REC
LOAK	wet	1	<.0015	0.097	0.027	0.012	0.136	85
LOAK	wet	2	<.00083	0.059	0.022	0.0071	0.088	45
LOAK	wet	3	<.00099	0.053	0.02	0.071	0.08	38
LOAK	wet	4	<.0013	0.165	0.043	0.019	0.227	31
UOAK	wet	1	0.043	1.267	0.746	0.237	2.293	52
UOAK	wet	2	0.03	1.901	0.269	0.138	2.338	72
UOAK	wet	3	0.011	0.679	0.23	0.137	1.057	63
LOAK	ad*	1	<.0023	0.046	0.04	0.01	0.096	50
LOAK	ad	2	<.0014	0.036	0.025	0.0047	0.065	57
LOAK	ad	3	<.0022	0.09	0.037	0.0033	0.13	42
LOAK	ad	4	<.0014	0.039	0.0099	0.0017	0.06	35
UOAK	ad	1	0.0021	0.228	0.159	0.01	0.399	49
UOAK	ad	2	<.0015	0.283	0.094	0.0056	0.282	37
UOAK	ad	3	0.0023	0.248	0.172	0.014	0.436	39
UOAK	ad	4	0.0025	0.339	0.308	0.024	0.673	40
LOAK	adw**	1	<.00084	0.02	0.023	0.011	0.054	12
LOAK	adw	2	<.0014	0.042	0.027	0.014	0.083	21
LOAK	adw	3	<.0019	0.196	0.061	0.0073	0.264	41
LOAK	adw	4	<.0013	0.022	0.018	0.0055	0.045	36
UOAK	adw	1	<.0013	0.219	0.086	0.012	0.317	61
UOAK	adw	2	<.0015	0.164	0.044	0.005	0.213	33
UOAK	adw	3	0.005	0.44	0.195	0.027	0.667	64
UOAK	adw	4	0.0056	0.476	0.23	0.041	0.752	60

No blanks, no standards, no QA/QC

\* Air dried

\*\* Air dried and washed

Table E-3  
Oakland Study - Washwater Heavy Metal Concentrations

OBS	SED	WASH_NO	REP	MG LCD	MG LCR	MG LHG	MG LNI	MG LZN
1	LOAK	1	1	.00046	.00452	4.1E-05	0.01299	0.027
2	LOAK	1	2	.00062	.00490	4.0E-05	0.00928	0.027
3	LOAK	1	3	.00062	.00512	4.1E-05	0.00928	0.030
4	LOAK	1	4	.00065	.00478	3.6E-05	0.00928	0.033
5	UOAK	1	1	.00087	.00352	4.4E-05	0.02226	0.030
6	UOAK	1	2	.00096	.00383	4.3E-05	0.02783	0.033
7	UOAK	1	3	.00111	.00428	5.4E-05	0.02597	0.037
8	UOAK	1	4	.00115	.00462	4.8E-05	0.02412	0.037
9	LOAK	2	1	.00028	.00476	7.8E-06	0.00742	0.013
10	LOAK	2	2	.00028	.00493	9.8E-06	0.00742	0.017
11	LOAK	2	3	.00022	.00483	4.5E-06	0.00742	0.013
12	LOAK	2	4	.00025	.00653	5.6E-06	0.00557	0.017
13	UOAK	2	1	.00031	.00225	7.4E-06	0.02041	0.017
14	UOAK	2	2	.00022	.00192	9.4E-06	0.01670	0.017
15	UOAK	2	3	.00025	0.00190	1.1E-05	0.02226	0.020
16	UOAK	2	4	.00025	0.00190	1.2E-05	0.02226	0.017
17	LOAK	3	1	.00046	0.03764	1.7E-04	0.02783	0.067
18	LOAK	3	2	.00046	0.01330	1.4E-04	0.02041	0.057
19	LOAK	3	3	.00046	0.02435	1.5E-04	0.02041	0.063
20	LOAK	3	4	.00053	0.01301	1.4E-04	0.02041	0.063
21	UOAK	3	1	.	0.00353	5.2E-06	0.02412	0.023
22	UOAK	3	2	.00006	0.00396	1.0E-05	0.02412	0.030
23	UOAK	3	3	.00009	0.00378	1.4E-05	0.02412	0.023
24	UOAK	3	4	.	0.00368	8.6E-06	0.02412	0.023
Blank washwater 1				0.00009	<0.00006	<0.0000001	<0.00186	<0.0058
Blank washwater 2				0.00012	<0.00006	0.0000013	<0.00186	<0.0058
Blank washwater 3				0.00016	0.0041	0.0000036	<0.00186	<0.0058
QA/QC								
Blank				0.0062	<0.00006	--	0.00557	<0.0058
SLRS-1				--	0.00031	--	--	--
cert					0.00036	--	--	--
value					±0.000004	--	--	--
1643c				0.0117	--	--	0.0557	0.067
cert				0.0100	--	--	0.0550	0.072
value				±0.0001	--	--	±0.0030	±0.004

Table E-4  
Oakland Study - Sediment Heavy Metal Concentration

OBS	SED	WASH_STA	REP	UG_GCD	UG_GCR	UG_GHG	UG_GNI	UG_GZN
1	LOAK	wet	1	0.36363	178.943	4.1917	70.787	100.316
2	LOAK	wet	2	0.35856	198.115	3.4973	68.195	95.506
3	LOAK	wet	3	0.43947	184.486	3.2733	67.260	99.080
4	LOAK	wet	4	0.51911	192.510	3.2221	65.626	101.233
5	UOAK	wet	1	1.57208	214.747	11.9024	114.457	236.403
6	UOAK	wet	2	1.05200	219.549	6.5297	110.633	226.002
7	UOAK	wet	3	1.36428	214.380	7.5882	117.388	247.765
8	UOAK	wet	4	0.98157	226.589	7.5069	116.130	245.985
9	LOAK	ad	1	0.18018	179.000	0.2903	56.576	82.939
10	LOAK	ad	2	0.26242	145.914	0.5638	51.776	63.065
11	LOAK	ad	3	0.23492	135.497	0.7571	52.569	68.184
12	LOAK	ad	4	0.26095	159.305	0.6307	55.254	75.119
13	UOAK	ad	1	0.62130	155.648	1.4301	86.492	170.958
14	UOAK	ad	2	0.71273	154.156	1.3638	87.462	181.132
15	UOAK	ad	3	0.62898	158.969	1.4478	88.858	168.585
16	UOAK	ad	4	0.62541	158.762	1.5836	89.644	166.992
17	LOAK	adw	1	0.22494	179.888	0.3170	50.118	65.135
18	LOAK	adw	2	0.22275	184.160	0.7063	47.149	71.702
19	LOAK	adw	3	0.22103	195.287	0.7008	48.016	53.882
20	LOAK	adw	4	0.20931	198.515	0.5162	61.793	61.174
21	UOAK	adw	1	0.54468	167.212	1.4391	83.623	151.578
22	UOAK	adw	2	0.60282	177.724	2.1502	88.771	159.231
23	UOAK	adw	3	0.89732	178.187	1.8967	93.091	167.079
24	UOAK	adw	4	0.82854	164.529	1.8243	92.878	166.547
25	TWIT	ad	1	0.44110	100.007	0.0232	59.539	81.638
26	TWIT	ad	2	0.27679	111.260	0.0333	62.804	84.807
27	TWIT	ad	3	0.20117	109.211	0.0368	59.677	82.182
28	TWIT	ad	4	0.35141	106.425	0.0250	61.997	82.623
29	7ST	ad	1	0.43369	132.268	0.0010	75.450	350.951
30	7ST	ad	2	0.32620	87.980	0.0078	124.692	340.005
31	7ST	ad	3	0.16377	96.287	0.0135	4.815	330.476
32	7ST	ad	4	0.27084	83.151	0.0166	76.452	323.054
Set Number				-----mg/L-----				
Blank 1				0.002	0.097	<0.001	0.01	0.12
Blank 2				0.003	0.085	<0.001	0.01	0.069
Blank 3				0.003	0.042	<0.001	0.01	0.125
Blank 4				0.002	0.034	<0.004	0.01	0.014
				-----% Recovery-----				
NBS 1645 1				38.51	48.86	16.89	57.37	53.97
NBS 1645 2				54.32	69.85	71.39	75.26	76.18
NBS 1645 3				66.29	81.73	66.91	79.34	82.03
NBS 1645 4				69.21	66.55	87.74	70.61	69.23

\* Values have been corrected to 100% using the appropriate NBS set.

Table E-5  
Sediment pH, Salinity, and Organic Matter as Affected by Washing

OBS	SED	WASH_STA	BUK_NO	WASH_NO	REP	PH	EC	SAL	OM
1	7ST	ad	1	0	1	7.50	.	.	.
2	7ST	ad	1	0	2	7.49	.	.	.
3	7ST	ad	1	0	3	7.51	.	.	.
4	7ST	ad	1	0	4	7.52	3.990	.	.
5	7ST	ad	1	0	5	7.49	3.980	.	.
6	LOAK	ad	1	0	1	7.61	36.100	.	.
7	LOAK	ad	1	0	2	7.63	37.400	.	.
8	LOAK	wet	1	0	1	8.17	28.900	20	1.84
9	LOAK	wet	1	0	2	8.14	.	.	1.94
10	LOAK	wet	1	0	3	8.15	.	.	1.99
11	LOAK	adw	1	1	1	7.38	18.700	16	.
12	LOAK	adw	1	1	2	7.39	21.900	18	.
13	LOAK	adw	1	1	3	7.36	17.400	14	.
14	TWIT	ad	1	0	1	4.83	.	.	.
15	TWIT	ad	1	0	2	4.86	.	.	.
16	TWIT	ad	1	0	3	4.53	0.716	.	.
17	TWIT	ad	1	0	4	4.52	0.693	.	.
18	TWIT	ad	1	0	5	4.57	0.706	.	.
19	UOAK	ad	1	0	1	7.48	55.300	.	.
20	UOAK	ad	1	0	2	7.45	55.300	.	.
21	UOAK	wet	1	0	1	7.88	36.300	26	5.07
22	UOAK	wet	1	0	2	7.86	.	.	5.21
23	UOAK	wet	1	0	3	7.90	.	.	5.23
24	UOAK	adw	1	1	1	7.69	26.200	20	.
25	UOAK	adw	1	1	2	7.71	27.500	22	.
26	UOAK	adw	1	1	3	7.72	28.600	22	.
1	7ST	ad	1	0	1	7.50	.	.	.
2	7ST	ad	1	0	2	7.49	.	.	.
3	7ST	ad	1	0	3	7.51	.	.	.
4	7ST	ad	1	0	4	7.52	3.990	.	.
5	7ST	ad	1	0	5	7.49	3.980	.	.
6	LOAK	ad	1	0	1	7.61	36.100	.	.
7	LOAK	ad	1	0	2	7.63	37.400	.	.
8	LOAK	wet	1	0	1	8.17	28.900	20	1.84
9	LOAK	wet	1	0	2	8.14	.	.	1.94
10	LOAK	wet	1	0	3	8.15	.	.	1.99
11	LOAK	wet	2	0	1	8.23	24.800	17	1.74
12	LOAK	wet	2	0	2	8.23	.	.	1.58
13	LOAK	wet	2	0	3	8.27	.	.	1.88
14	LOAK	wet	3	0	1	8.24	35.300	26	1.76
15	LOAK	wet	3	0	2	8.20	.	.	1.90
16	LOAK	wet	3	0	3	8.20	.	.	1.86
17	LOAK	wet	4	0	1	8.17	30.000	24	3.00
18	LOAK	wet	4	0	2	8.15	.	.	2.90
19	LOAK	wet	4	0	3	8.15	.	.	3.08
20	LOAK	adw	3	3	1	6.80	3.640	2	.



Table E-5 (continued)

21	LOAK	adw	3	3	2	6.76	3.720	2	.
22	LOAK	adw	3	3	3	6.77	3.730	2	.
23	TWIT	ad	1	0	1	4.83	.	.	.
24	TWIT	ad	1	0	2	4.86	.	.	.
25	TWIT	ad	1	0	3	4.53	0.716	.	.
26	TWIT	ad	1	0	4	4.52	0.693	.	.
27	TWIT	ad	1	0	5	4.57	0.706	.	.
28	UOAK	ad	1	0	1	7.48	55.300	.	.
29	UOAK	ad	1	0	2	7.45	55.300	.	.
30	UOAK	wet	1	0	1	7.88	36.300	26	5.07
31	UOAK	wet	1	0	2	7.86	.	.	5.21
32	UOAK	wet	1	0	3	7.90	.	.	5.23
33	UOAK	wet	2	0	1	7.92	31.200	25	5.39
34	UOAK	wet	2	0	2	7.91	.	.	5.36
35	UOAK	wet	2	0	3	7.91	.	.	5.40
36	UOAK	wet	3	0	1	7.88	35.100	24	5.00
37	UOAK	wet	3	0	2	7.86	.	.	4.88
38	UOAK	wet	3	0	3	7.85	.	.	4.97
39	UOAK	wet	4	0	1	7.88	30.300	24	5.13
40	UOAK	wet	4	0	2	7.87	.	.	4.84
41	UOAK	wet	4	0	3	7.88	.	.	5.21
42	UOAK	adw	3	3	1	6.74	11.400	8	.
43	UOAK	adw	3	3	2	6.71	11.000	8	.
44	UOAK	adw	3	3	3	6.76	11.100	8	.

Table E-6

## Oakland Study - DTPA Metals in Sediment

OBS	SED	WASH_STA	REP	UG_GCD	UG_GCR	UG_GHG	UG_GNI	UG_GZN
1	LOAK	wet	1	0.17932	0.00000	0	3.38717	26.4498
2	LOAK	wet	2	0.16541	0.00000	0	3.35692	24.1309
3	LOAK	wet	3	0.16234	0.00000	0	3.34526	23.7612
4	LOAK	wet	4	0.16300	0.00000	0	3.03965	22.9515
5	UOAK	wet	1	0.17279	0.31596	0	4.93689	27.9922
6	UOAK	wet	2	0.31979	0.37883	0	5.80544	49.8382
7	UOAK	wet	3	0.29884	0.37232	0	5.78081	46.4914
8	UOAK	wet	4	0.19715	0.29573	0	5.11663	30.5120
9	LOAK	ad	1	0.25562	0.00983	0	2.16292	26.7416
10	LOAK	ad	2	0.22791	0.01455	0	1.93961	23.1299
11	LOAK	ad	3	0.21633	0.00492	0	1.77001	22.6659
12	LOAK	ad	4	0.20926	0.00996	0	1.74381	22.4205
13	UOAK	ad	1	0.53853	0.24932	0	5.03627	70.6574
14	UOAK	ad	2	0.52027	0.29940	0	4.56466	65.1323
15	UOAK	ad	3	0.56434	0.30916	0	4.51472	69.5365
16	UOAK	ad	4	0.58108	0.26368	0	4.59005	73.5873
17	LOAK	adw	1	0.18549	0.00488	0	1.95254	13.6922
18	LOAK	adw	2	0.18075	0.02931	0	1.85634	13.2142
19	LOAK	adw	3	0.18464	0.01458	0	1.79777	13.7748
20	LOAK	adw	4	0.16931	0.00967	0	1.78987	13.1821
21	UOAK	adw	1	0.55040	0.00000	0	5.55228	59.1680
22	UOAK	adw	2	0.49770	0.00000	0	5.72356	53.0300
23	UOAK	adw	3	0.48945	0.00000	0	4.74765	52.1507
24	UOAK	adw	4	0.48360	0.00000	0	4.73632	50.6288
25	TWIT	ad	1	0.23735	0.02792	.	9.12185	8.2748
26	TWIT	ad	2	0.24211	0.01862	.	9.40513	8.6043
27	TWIT	ad	3	0.22350	0.01863	.	8.42797	7.9065
28	TWIT	ad	4	0.23768	0.01398	.	9.13449	8.3795
29	7ST	ad	1	0.14209	0.09310	.	1.96971	23.3131
30	7ST	ad	2	0.13225	0.08817	.	1.77317	60.1409
31	7ST	ad	3	0.14686	0.08322	.	2.01193	30.2915
32	7ST	ad	4	0.13695	0.08804	.	1.79014	22.9783

		-----ug/ml-----				
QA/QC	DTPA blank 1	0.002	0.005	<0.001	0.01	0.070
	DTPA blank 2	0.002	0.003	<0.001	0.01	0.030
	DTPA blank 3	0.002	0.005	<0.001	0.01	0.045
	DTPA blank 4	0.002	0.005	<0.004	0.01	0.022
NBS SRM 1643B Ref 1		0.02	0.017	--	0.046	0.066
Cert		0.02	0.0186	--	0.049	0.066
value		±0.001	±0.0004	--	±0.003	±0.002
%recovery		100.0	91.4	--	93.9	100.0
NBS SRM 1643B Ref 2		0.021	0.017	--	0.046	0.064
Cert		0.02	0.0186	--	0.049	0.066
value		±0.001	±0.0004	--	±0.003	±0.002
%recovery		105.0	91.4	--	93.9	97.0
NRCC DQLT-1		--	--	0.248	--	--
Cert		--	--	0.225	--	--
value		--	--	±0.037	--	--

\* Values were not corrected to 100% of NBS.

Table E-7  
Oakland Study - Plant Yields

OBS	SED	PLANT	WASHSTA	REP	T_YIELD
1	7ST	CYP	Y	1	6.8197
2	7ST	CYP	Y	2	6.0350
3	7ST	CYP	Y	3	4.7132
4	7ST	CYP	Y	4	5.1832
5	LOAK	CYP	Y	1	6.9227
6	LOAK	CYP	Y	2	6.7415
7	LOAK	CYP	Y	3	6.1238
8	LOAK	CYP	Y	4	6.0990
9	TWIT	CYP	Y	1	36.1211
10	TWIT	CYP	Y	2	45.7079
11	TWIT	CYP	Y	3	41.7801
12	TWIT	CYP	Y	4	44.6143
13	UOAK	CYP	Y	1	18.8544
14	UOAK	CYP	Y	2	21.1947
15	UOAK	CYP	Y	3	20.4750
16	UOAK	CYP	Y	4	22.2273
17	7ST	SPOR	N	1	2.6479
18	7ST	SPOR	N	2	5.5280
19	7ST	SPOR	N	3	2.7072
20	7ST	SPOR	N	4	3.0420
21	LOAK	SPOR	N	1	7.7483
22	LOAK	SPOR	N	2	6.8212
23	LOAK	SPOR	N	3	5.1415
24	LOAK	SPOR	N	4	5.2600
25	TWIT	SPOR	N	1	34.2552
26	TWIT	SPOR	N	2	31.3874
27	TWIT	SPOR	N	3	27.3766
28	TWIT	SPOR	N	4	27.0606
29	UOAK	SPOR	N	1	6.8670
30	UOAK	SPOR	N	2	17.2554
31	UOAK	SPOR	N	3	0.5950
32	UOAK	SPOR	N	4	16.2054
33	LOAK	SPOR	Y	1	4.5907
34	LOAK	SPOR	Y	2	5.4281
35	LOAK	SPOR	Y	3	3.6487
36	LOAK	SPOR	Y	4	3.9663
37	UOAK	SPOR	Y	1	14.2914
38	UOAK	SPOR	Y	2	14.7811
39	UOAK	SPOR	Y	3	14.9084
40	UOAK	SPOR	Y	4	12.8919

Table E-8  
Oakland Study - Plant Tissue Heavy Metal Concentration

OBS	SED	SPECIES	WASH_STA	REP	UG_GCD	UG_GCR	UG_GHG	UG_GNI	UG_GZN
1	UOAK	cyp	adw	1	4.77917*	0.33118	0.006430	4.9854	131.511
2	UOAK	cyp	adw	2	3.79275	0.36744	0.003120	4.4286	134.593
3	UOAK	cyp	adw	3	4.74885	1.40351	0.004170	4.7624	135.468
4	UOAK	cyp	adw	4	5.25701	0.33135	0.004650	6.1649	148.690
5	LOAK	cyp	adw	1	3.13303	0.92824	0.010710	6.5360	112.505
6	LOAK	cyp	adw	2	3.60331	0.60907	0.011200	7.7756	117.030
7	LOAK	cyp	adw	3	3.24333	0.68920	0.021570	7.9305	107.080
8	LOAK	cyp	adw	4	3.51105	1.10955	0.012450	7.1952	124.051
9	7ST	cyp	adw	1	0.86564	0.49015	.	2.7059	119.101
10	7ST	cyp	adw	2	0.92247	0.41108	0.000820	3.2239	137.014
11	7ST	cyp	adw	3	0.98122	0.39396	.	3.5584	147.851
12	7ST	cyp	adw	4	0.91414	0.50142	0.011350	3.5203	129.045
13	TWIT	cyp	adw	1	4.33191	0.33118	.	9.7648	108.703
14	TWIT	cyp	adw	2	3.24495	0.41108	0.003053	10.1426	100.419
15	TWIT	cyp	adw	3	3.60691	0.25182	.	10.2847	96.677
16	TWIT	cyp	adw	4	3.18581	0.25170	.	9.9119	99.983
17	UOAK	spor	adw	1	0.55842	0.72896	.	3.9579	34.933
18	UOAK	spor	adw	2	0.97745	2.59646	.	5.3530	41.623
19	UOAK	spor	adw	3	0.53019	0.13247	.	3.4412	28.140
20	UOAK	spor	adw	4	0.67030	0.17230	.	3.2958	37.617
21	LOAK	spor	adw	1	0.53317	1.64626	.	3.4944	30.459
22	LOAK	spor	adw	2	0.61682	0.37260	.	2.8659	44.507
23	LOAK	spor	adw	3	0.63437	0.46851	.	3.2321	58.929
24	LOAK	spor	adw	4	0.61752	0.23827	.	3.2351	47.843
25	UOAK	spor	ad	1	0.30656	0.09273	.	2.6324	51.685
26	UOAK	spor	ad	2	0.61405	0.17221	.	2.7794	36.928
27	UOAK	spor	ad	4	0.44633	0.17221	.	3.4412	43.971
28	LOAK	spor	ad	1	0.39062	0.25182	.	2.7808	33.590
29	LOAK	spor	ad	2	0.41467	0.41054	0.031230	3.6278	40.371
30	LOAK	spor	ad	3	0.29723	0.01768	0.020600	2.9245	47.048
31	LOAK	spor	ad	4	0.31283	0.10412	.	2.9557	35.965
32	7ST	spor	ad	1	0.68930	0.00000	0.029240	1.3750	68.346
33	7ST	spor	ad	2	0.60131	0.12493	.	1.6643	67.373
34	7ST	spor	ad	3	0.40930	0.00000	.	0.8165	60.849
35	7ST	spor	ad	4	0.24638	0.02944	0.020540	0.7842	62.378
36	TWIT	spor	ad	1	0.72550	1.32406	.	5.2768	31.143
37	TWIT	spor	ad	2	0.72659	1.32605	.	5.1376	29.008
38	TWIT	spor	ad	3	0.75420	0.92777	.	4.3257	32.584
39	TWIT	spor	ad	4	0.75458	1.36583	0.003320	4.8431	31.962
					-----mg/L-----				
Blank 1					0.0021	0.042	<0.000004	0.014	0.089
Blank 2					0.00077	0.031	<0.000004	<0.0083	0.021
Blank 3					0.00023	0.031	<0.000004	<0.0083	0.007
QA/QC					11	--	--	53	--
Cert					10	--	--	55	--
value					±1	--	--	±3	
					-----% Recovery-----				
NBS SRM 1572 1					68.13	58.10	60.68	12.77	72.95
NBS SRM 1572 2					119.1	68.72	1.91	36.23	77.29
NBS SRM 1572 3					80.79	68.72	--	52.89	78.32

\* Values were corrected to 100% NBS.

Table E-9  
Oakland Study - Total Plant Uptake of Heavy Metals

OBS	SED	SPECIES	WASH STA	REP	MGCD POT	MCCR POT	MGHG POT	MGNI POT
1	UOAK	cyp	adw	1	0.08317	5.8E-03	3.7E-07	0.08676
2	UOAK	cyp	adw	2	0.07777	7.5E-03	1.5E-07	0.09080
3	UOAK	cyp	adw	3	0.09096	2.7E-02	2.2E-07	0.09122
4	UOAK	cyp	adw	4	0.10837	6.8E-03	2.3E-07	0.12709
5	LOAK	cyp	adw	1	0.01869	5.5E-03	1.8E-06	0.03899
6	LOAK	cyp	adw	2	0.02056	3.5E-03	2.0E-06	0.04437
7	LOAK	cyp	adw	3	0.01682	3.6E-03	4.2E-06	0.04112
8	LOAK	cyp	adw	4	0.01802	5.7E-03	2.4E-06	0.03693
9	7ST	cyp	adw	1	0.00493	2.8E-03	.	0.01541
10	7ST	cyp	adw	2	0.00449	2.0E-03	1.7E-07	0.01568
11	7ST	cyp	adw	3	0.00393	1.6E-03	.	0.01424
12	7ST	cyp	adw	4	0.00403	2.2E-03	2.6E-06	0.01552
13	TWIT	cyp	adw	1	0.15214	1.2E-02	.	0.34294
14	TWIT	cyp	adw	2	0.14466	1.8E-02	6.8E-08	0.45215
15	TWIT	cyp	adw	3	0.14383	1.0E-02	.	0.41012
16	TWIT	cyp	adw	4	0.13802	1.1E-02	.	0.42943
17	UOAK	spor	adw	1	0.00650	8.5E-03	.	0.04610
18	UOAK	spor	adw	2	0.01181	3.1E-02	.	0.06469
19	UOAK	spor	adw	3	0.00590	1.5E-03	.	0.03830
20	UOAK	spor	adw	4	0.00710	1.8E-03	.	0.03491
21	LOAK	spor	adw	1	0.00279	8.6E-03	.	0.01831
22	LOAK	spor	adw	2	0.00792	4.8E-03	.	0.03679
23	LOAK	spor	adw	3	0.00804	5.9E-03	.	0.04097
24	LOAK	spor	adw	4	0.00180	7.0E-04	.	0.00944
25	UOAK	spor	ad	1	0.00115	3.5E-04	.	0.00983

OBS	MGZN_POT	UGCD_POT	UGCR_POT	UGHG_POT	UGNI_POT	UGZN_POT
1	2.28873	83.174	5.7637	0.000369	86.762	2288.73
2	2.75967	77.765	7.5338	0.000152	90.803	2759.67
3	2.59489	90.964	26.8842	0.000217	91.224	2594.89
4	3.06515	108.370	6.8305	0.000226	127.086	3065.15
5	0.67117	18.691	5.5376	0.001800	38.992	671.17
6	0.66783	20.562	3.4757	0.001960	44.372	667.83
7	0.55518	16.816	3.5733	0.004160	41.118	555.18
8	0.63675	18.022	5.6953	0.002430	36.932	636.75
9	0.67824	4.930	2.7912	.	15.409	678.24
10	0.66630	4.486	1.9991	0.000169	15.678	666.30
11	0.59159	3.926	1.5764	.	14.238	591.59
12	0.56886	4.030	2.2104	0.002570	15.518	568.86
13	3.81768	152.137	11.6311	.	342.942	3817.68
14	4.47655	144.656	18.3253	0.000068	452.146	4476.55
15	3.85520	143.833	10.0420	.	410.123	3855.20
16	4.33169	138.023	10.9046	.	429.425	4331.69
17	0.40687	6.504	8.4905	.	46.099	406.87
18	0.50298	11.812	31.3759	.	64.686	502.98
19	0.31321	5.901	1.4745	.	38.302	313.21
20	0.39848	7.100	1.8252	.	34.912	398.48

Table E-9 (continued)

21	0.15957	2.793	8.6247	.	18.307	159.57
22	0.57130	7.918	4.7828	.	36.787	571.30
23	0.74700	8.042	5.9390	.	40.971	747.00
24	0.13959	1.802	0.6952	.	9.439	139.59
25	0.19305	1.145	0.3464	.	9.832	193.05

OBS	SED	SPECIES	WASH_STA	REP	MGCD_POT	MGCR_POT	MGHG_POT	MGNI_POT
26	UOAK	spor	ad	2	0.00181	5.1E-04	.	0.00817
27	UOAK	spor	ad	4	0.00137	5.3E-04	.	0.01056
28	LOAK	spor	ad	1	0.00198	1.3E-03	.	0.01413
29	LOAK	spor	ad	2	0.00158	1.6E-03	8.2E-06	0.01383
30	LOAK	spor	ad	3	0.00089	5.3E-05	6.9E-06	0.00873
31	LOAK	spor	ad	4	0.00104	3.5E-04	.	0.00979
32	7ST	spor	ad	1	0.00091	0.0E+00	2.2E-05	0.00181
33	7ST	spor	ad	2	0.00176	3.7E-04	.	0.00487
34	7ST	spor	ad	3	0.00086	0.0E+00	.	0.00172
35	7ST	spor	ad	4	0.00039	4.7E-05	1.3E-05	0.00125
36	TWIT	spor	ad	1	0.01997	3.6E-02	.	0.14527
37	TWIT	spor	ad	2	0.01800	3.3E-02	.	0.12724
38	TWIT	spor	ad	3	0.01676	2.1E-02	.	0.09613
39	TWIT	spor	ad	4	0.01656	3.0E-02	1.5E-07	0.10630

OBS	MGZN_POT	UGCD_POT	UGCR_POT	UGHG_POT	UGNI_POT	UGZN_POT
26	0.10855	1.805	0.5062	.	8.171	108.55
27	0.13492	1.369	0.5284	.	10.559	134.92
28	0.17065	1.984	1.2793	.	14.127	170.65
29	0.15390	1.581	1.5651	0.008190	13.830	153.90
30	0.14051	0.888	0.0528	0.006900	8.734	140.51
31	0.11918	1.037	0.3450	.	9.795	119.18
32	0.09001	0.908	0.0000	0.022200	1.811	90.01
33	0.19720	1.760	0.3657	.	4.871	197.20
34	0.12822	0.862	0.0000	.	1.720	128.22
35	0.09950	0.393	0.0470	0.012900	1.251	99.50
36	0.85735	19.973	36.4504	.	145.267	857.35
37	0.71841	17.995	32.8415	.	127.239	718.41
38	0.72413	16.761	20.6184	.	96.134	724.13
39	0.70149	16.561	29.9767	0.000152	106.295	701.49

APPENDIX F: ANIMAL TEST

# APPENDIX F ANIMAL TEST

Table F1 Concentrations of Metals in Substrates and Tissues of Bioassay Earthworms (ug/g dry weight)

Substrate	Metal								
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Time = 0	0.05	28.5	8.65	0.59	18.0	0.079	1.03	2.92	147
Reference Tissue									
Rep 1	0.01	87.1	7.66	0.17	18.2	0.050	0.92	0.52	152
Rep 2		21.6	6.44	0.18	13.3	0.037	0.74	0.57	162
Rep 3									
Split 1		19.2	7.47	0.15	16.4	0.047	0.71	0.48	153
Split 2		17.0	7.64	0.15	17.3	0.046	0.73	0.56	149
Rep 4									
Split 1		25.5	6.11	0.11	14.7	0.036	0.59	0.34	140
Split 2		38.3	6.35	0.10	17.5	0.044	0.68	0.44	155
Mean Tissue		26.45	6.94	0.14	16.24	0.042	0.73	0.49	151.8
		(8.37)	(0.66)	(0.03)	(1.72)	(0.006)	(0.10)	(0.08)	(6.6)
7th Street									
Soil	0.62	24.5	0.58	348.0	563.0	0.346	65.0	120.0	303
Tissue									
Rep 1	0.28	49.2	6.14	0.81	51.3	0.358	7.52	4.15	165
Rep 2	0.24	48.6	6.91	3.30	70.0	0.418	9.18	5.88	170
Rep 3	0.25	35.2	6.69	0.68	60.6	0.374	6.26	2.52	155
Rep 4	0.37	37.5	5.48	29.61	58.6	0.369	20.14	5.47	173
Mean Tissue	0.28	42.6	6.30	8.60	60.1	0.379	10.77	4.50	151.8
	(0.05)	(6.3)	(0.55)	(12.17)	(6.7)	(0.023)	(5.50)	(1.31)	(6.6)
Twitchell I.									
Soil	0.14	14.7	0.46	129.0	41.0	0.214	73.0	13.0	96
Tissue									
Rep 1	0.16	35.2	6.02	5.76	28.0	0.400	20.45	1.96	152
Rep 2	0.16	32.9	8.09	1.49	16.5	0.468	11.51	0.69	133
Rep 3	0.16	44.3	8.20	7.07	20.0	0.426	20.78	1.85	132
Rep 4	<0.01	26.7	8.47	2.45	18.5	0.396	12.33	1.07	138
Mean Tissue	<0.12	34.8	7.69	4.19	20.75	0.422	16.27	1.39	138.7
	(0.06)	(6.3)	(0.98)	(2.29)	(4.37)	(0.029)	(4.36)	(0.53)	(8.0)



Table F1 continued Concentrations of Metals in Substrates and Tissues  
of Bioassay Earthworms (ug/g dry weight)

Substrate	Metal								
	Ag	As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Lower Sed.									
Sediment	0.25	5.4	0.37	585.75	40.75	0.540	67.75	22.75	78.5
		(0.9)	(0.2)	(58.5)	(13.1)	(0.02)	(2.1)	(9.6)	(12.2)
Tissue									
Rep 1	<0.01	86.6	8.38	3.58	24.5	0.297	5.37	1.46	141
Rep 2	0.05	26.7	7.30	3.88	25.8	0.253	8.95	1.58	134
Rep 3	0.05	47.7	8.16	2.49	34.2	0.279	5.20	1.33	124
Rep 4	0.07	49.1	6.62	0.92	21.9	0.241	12.59	4.40	133
Mean Tissue	<0.04	52.5	7.61	2.71	26.6	0.267	8.03	1.94	133
	(0.02)	(21.6)	(0.70)	(1.16)	(4.6)	(0.022)	(3.03)	(1.47)	(6.0)
Upper Sed.									
Sediment	0.74	10.15	0.96	321.25	102.5	1.010	116.5	83.75	218
		(2.0)	(0.2)	(10.8)	(12.5)	(0.1)	(4.5)	(14.4)	
Tissue									
Rep 1	0.09	35.8	7.13	4.28	30.5	0.348	12.72	4.29	148
Rep 2	0.12	49.5	7.07	0.61	28.1	0.234	6.34	1.64	140
Rep 3	0.07	78.2	7.88	1.44	24.2	0.215	8.76	2.58	137
Rep 4	0.12	89.0	6.85	1.77	25.0	0.210	8.34	2.74	156
Mean Tissue	0.10	63.1	7.23	2.02	26.9	0.252	9.04	2.74	145.2
	(0.02)	(21.4)	(0.39)	(1.37)	(2.5)	(0.056)	(2.31)	(0.96)	(7.4)

Table F2 Concentrations of Organotins in Tissues of Bioassay Earthworms  
(ug/kg dry weight as butyltin cations)

Substrate	Butyltin Concentrations				
	Tetra	Tri	Di	Mono	Total
Time=0	<12.0	18.0	23.0	14.0	55
Reference					
Tissue					
Rep 1	3.2	5.5	15.0	<3.2	24
Rep 2	<1.8	3.2	8.3	5.0	17
Rep 3	<4.0	6.0	<4.2	<4.4	6
Rep 4	<4.9	7.6	22.0	7.6	37
Mean Tissue	<3.3 (1.4)	5.6 (1.6)	<12.4 (6.8)	<5.1 (1.6)	12 (11.2)
7th Street					
Soil	-	<0.2	0.2	0.2	-
Tissue					
Rep 1	<2.0	22.0	28.0	3.5	54
Rep 2	<11.0	39.0	142.0	32.0	213
Rep 3	<4.3	14.0	24.0	4.7	43
Rep 4	<2.5	9.0	20.0	2.7	32
Mean Tissue	<4.9 (3.6)	21.0 (11.4)	53.5 (51.2)	10.7 (12.3)	85.5 (74.0)
Twitchell I.					
Soil	-	<0.2	<0.2	<0.2	<0.2
Tissue					
Rep 1	<3.9	3.4	4.8	1.8	10
Rep 2	<1.9	10.0	42.0	11.0	63
Rep 3	<0.69	5.1	13.0	3.0	21
Rep 4	<0.92	4.2	12.0	2.2	18
Mean Tissue	<1.85 (1.27)	5.7 (2.6)	17.9 (14.2)	4.5 (3.8)	28 (20.6)

Table F2 continued      Concentrations of Organotins in Tissues of Bioassay  
Earthworms  
(ug/kg dry weight as butyltin cations)

Lower Sed Sediment	-	35.0 (40)	7.0 (5.0)	2.0 (1.0)	44
Tissue					
Rep 1	<3.9	111.0	64.0	10.0	185
Rep 2	<4.8	77.0	48.0	11.0	136
Rep 3	<5.1	101.0	54.0	8.6	164
Rep 4	<6.2	76.0	44.0	11.0	131
Substrate		Butyltin Concentrations			
	Tetra	Tri	Di	Mono	Total
Mean Tissue	<5.0 (0.8)	91.3 (15.2)	52.5 (7.5)	10.1 (1.0)	154 (21.9)
Upper Sed Sediment	-	702 (560)	153 (130)	19.0 (10.0)	874
Tissue					
Rep 1	7.9	596.0	228.0	22.0	854
Rep 2	1.8	622.0	211.0	10.0	845
Rep 3	2.4	611.0	258.0	16.0	887
Rep 4	3.9	637.0	223.0	22.0	886
Mean Tissue	4.0 (2.4)	616.5 (15.0)	228 (17.9)	17.5 (5.0)	868 (18.8)

Key to Sample ID

T1-1	Twitchell Island
US-1	Upper Sediment
RF-1	Reference Substrate
Ott 7th St.-2	7th Street Disposal Site
LS-1	Lower Sediment

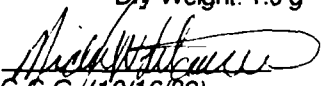
# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 1002MB  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/06/89  
Conc/Dil Factor: 1:10  
Dry Weight: 1.0 g

Sample No.: Method Blank  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized:   
DATA PREPARED: MAC: C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	5.0 U
319-85-7	Beta-BHC	7.5 U
319-86-8	Delta-BHC	10 U
58-89-9	Gamma-BHC (Lindane)	5.0 U
76-44-8	Heptachlor	5.0 U
309-00-2	Aldrin	7.5 U
1024-57-3	Heptachlor Epoxide	7.5 U
959-98-8	Endosulfan I	7.5 U
60-57-1	Dieldrin	10 U
72-55-9	4,4'-DDE	10 U
72-20-8	Endrin	10 U
33212-65-9	Endosulfan II	10 U
72-54-8	4,4'-DDD	15 U
1031-07-8	Endosulfan Sulfate	23 U
50-29-3	4,4'-DDT	15 U
72-43-5	Methoxychlor	20 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	7.5 U
5103-71-9	Alpha-Chlordane	7.5 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	74%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 A  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/06/89  
Conc/Dil Factor: 1:10  
Dry Weight: 1.7 g

Sample No.: T1-1  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: *[Signature]*  
DATA PREPARED: MAC/C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	120 U
319-85-7	Beta-BHC	75 U
319-86-8	Delta-BHC	40 U
58-89-9	Gamma-BHC (Lindane)	40 U
76-44-8	Heptachlor	10 U
309-00-2	Aldrin	45 U
1024-57-3	Heptachlor Epoxide	45 U
959-98-8	Endosulfan I	15 U
60-57-1	Dieldrin	10 U
72-55-9	4,4'-DDE	180
72-20-8	Endrin	10 U
33212-65-9	Endosulfan II	10 U
72-54-8	4,4'-DDD	30 U
1031-07-8	Endosulfan Sulfate	45 U
50-29-3	4,4'-DDT	270
72-43-5	Methoxychlor	35 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	15 U
5103-71-9	Alpha-Chlordane	15 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	72%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 B  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/06/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.7 g

Sample No.: T1-2  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: *[Signature]*  
DATA PREPARED: MAC:C C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	130 U
319-85-7	Beta-BHC	110 U
319-86-8	Delta-BHC	60 U
58-89-9	Gamma-BHC (Lindane)	60 U
76-44-8	Heptachlor	20 U
309-00-2	Aldrin	45 U
1024-57-3	Heptachlor Epoxide	45 U
959-98-8	Endosulfan I	20 U
60-57-1	Dieldrin	10 U
72-55-9	4,4'-DDE	330
72-20-8	Endrin	25 U
33212-65-9	Endosulfan II	25 U
72-54-8	4,4'-DDD	59
1031-07-8	Endosulfan Sulfate	65 U
50-29-3	4,4'-DDT	400
72-43-5	Methoxychlor	150 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	10 U
5103-71-9	Alpha-Chlordane	10 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	82%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

## F11



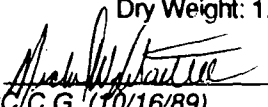
# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 D  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/06/89  
Conc/Dil Factor: 1:10  
Dry Weight: 1.19 g

Sample No.: T1-4  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized:   
DATA PREPARED: MAC/C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	300 U
319-85-7	Beta-BHC	100 U
319-86-8	Delta-BHC	75 U
58-89-9	Gamma-BHC (Lindane)	75 U
76-44-8	Heptachlor	10 U
309-00-2	Aldrin	60 U
1024-57-3	Heptachlor Epoxide	70 U
959-98-8	Endosulfan I	45 U
60-57-1	Dieldrin	10 U
72-55-9	4,4'-DDE	300
72-20-8	Endrin	35 U
33212-65-9	Endosulfan II	35 U
72-54-8	4,4'-DDD	50 U
1031-07-8	Endosulfan Sulfate	70 U
50-29-3	4,4'-DDT	360
72-43-5	Methoxychlor	200 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	15 U
5103-71-9	Alpha-Chlordane	15 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorendate	72%
--------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 E  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.9 g

Sample No.: US-1  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: *Michael J. Battelle*  
DATA PREPARED: MAC/C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	160 U
319-85-7	Beta-BHC	85 U
319-86-8	Delta-BHC	45 U
58-89-9	Gamma-BHC (Lindane)	50 U
76-44-8	Heptachlor	60 U
309-00-2	Aldrin	60 U
1024-57-3	Heptachlor Epoxide	100 U
959-98-8	Endosulfan I	50 U
60-57-1	Dieldrin	75 U
72-55-9	4,4'-DDE	160 U
72-20-8	Endrin	90 U
33212-65-9	Endosulfan II	90 U
72-54-8	4,4'-DDD	100 U
1031-07-8	Endosulfan Sulfate	55 U
50-29-3	4,4'-DDT	350 U
72-43-5	Methoxychlor	60 U
53494-70-5	Endrin Ketone	20 U
5103-74-2	Gamma-Chlordane	60 U
5103-71-9	Alpha-Chlordane	60 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1500 U
12672-29-6	Aroclor-1248	1500 U
11097-69-1	Aroclor-1254	2500
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	69%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 F  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 1.01 g

Sample No.: US-2  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: *Michael J. Hitt*  
DATA PREPARED: MAC/C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	110 U
319-85-7	Beta-BHC	60 U
319-86-8	Delta-BHC	60 U
58-89-9	Gamma-BHC (Lindane)	45 U
76-44-8	Heptachlor	30 U
309-00-2	Aldrin	55 U
1024-57-3	Heptachlor Epoxide	120 U
959-98-8	Endosulfan I	35 U
60-57-1	Dieldrin	75 U
72-55-9	4,4'-DDE	160 U
72-20-8	Endrin	40 U
33212-65-9	Endosulfan II	25 U
72-54-8	4,4'-DDD	150 U
1031-07-8	Endosulfan Sulfate	60 U
50-29-3	4,4'-DDT	550 U
72-43-5	Methoxychlor	120 U
53494-70-5	Endrin Ketone	20 U
5103-74-2	Gamma-Chlordane	80 U
5103-71-9	Alpha-Chlordane	30 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1500 U
12672-29-6	Aroclor-1248	1500 U
11097-69-1	Aroclor-1254	3600
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	73%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 G  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.81 g

Sample No.: US-3  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: *Michael Battelle*

DATA PREPARED: MAC: C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	200 U
319-85-7	Beta-BHC	150 U
319-86-8	Delta-BHC	75 U
58-89-9	Gamma-BHC (Lindane)	80 U
76-44-8	Heptachlor	40 U
309-00-2	Aldrin	60 U
1024-57-3	Heptachlor Epoxide	130 U
959-98-8	Endosulfan I	40 U
60-57-1	Dieldrin	40 U
72-55-9	4,4'-DDE	160 U
72-20-8	Endrin	60 U
33212-65-9	Endosulfan II	15 U
72-54-8	4,4'-DDD	150 U
1031-07-8	Endosulfan Sulfate	70 U
50-29-3	4,4'-DDT	500 U
72-43-5	Methoxychlor	90 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	70 U
5103-71-9	Alpha-Chlordane	50 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1500 U
12672-29-6	Aroclor-1248	1500 U
11097-69-1	Aroclor-1254	2700
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorendate	80%
--------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 H  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.67 g

Sample No.: US-4  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: *[Signature]*

DATA PREPARED: MAC: C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	140 U
319-85-7	Beta-BHC	80 U
319-86-8	Delta-BHC	50 U
58-89-9	Gamma-BHC (Lindane)	35 U
76-44-8	Heptachlor	10 U
309-00-2	Aldrin	30 U
1024-57-3	Heptachlor Epoxide	80 U
959-98-8	Endosulfan I	50 U
60-57-1	Dieldrin	40 U
72-55-9	4,4'-DDE	90 U
72-20-8	Endrin	15 U
33212-65-9	Endosulfan II	40 U
72-54-8	4,4'-DDD	80 U
1031-07-8	Endosulfan Sulfate	35 U
50-29-3	4,4'-DDT	220 U
72-43-5	Methoxychlor	25 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	40 U
5103-71-9	Alpha-Chlordane	10 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1500 U
12672-29-6	Aroclor-1248	1500 U
11097-69-1	Aroclor-1254	1900
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchloroendate	43%
---------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 I  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 2.24 g

Sample No.: RF-1  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

Data Release Authorized: 

DATA PREPARED: MAC: C.C.G. (10/16/89)

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

CAS Number		µg/kg
319-84-6	Alpha-BHC	90 U
319-85-7	Beta-BHC	90 U
319-86-8	Delta-BHC	200 U
58-89-9	Gamma-BHC (Lindane)	210 U
76-44-8	Heptachlor	20 U
309-00-2	Aldrin	25 U
1024-57-3	Heptachlor Epoxide	70 U
959-98-8	Endosulfan I	20 U
60-57-1	Dieldrin	35 U
72-55-9	4,4'-DDE	10 U
72-20-8	Endrin	50 U
33212-65-9	Endosulfan II	40 U
72-54-8	4,4'-DDD	45 U
1031-07-8	Endosulfan Sulfate	40 U
50-29-3	4,4'-DDT	50 U
72-43-5	Methoxychlor	200 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	25 U
5103-71-9	Alpha-Chlordane	25 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	64%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 J  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 2.17 g

Sample No.: RF-2  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: *Mike Stettin*

DATA PREPARED: MAC: C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	140 U
319-85-7	Beta-BHC	110 U
319-86-8	Delta-BHC	75 U
58-89-9	Gamma-BHC (Lindane)	50 U
76-44-8	Heptachlor	10 U
309-00-2	Aldrin	100 U
1024-57-3	Heptachlor Epoxide	80 U
959-98-8	Endosulfan I	40 U
60-57-1	Dieldrin	30 U
72-55-9	4,4'-DDE	35 U
72-20-8	Endrin	35 U
33212-65-9	Endosulfan II	55 U
72-54-8	4,4'-DDD	65 U
1031-07-8	Endosulfan Sulfate	40 U
50-29-3	4,4'-DDT	60 U
72-43-5	Methoxychlor	20 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	25 U
5103-71-9	Alpha-Chlordane	45 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodane	70%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

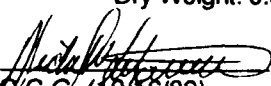
# **ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB**

Lab Sample ID: 3660 K  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.65 g

Sample No.: RF-3  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized:   
DATA PREPARED: MAC: C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	160 U
319-85-7	Beta-BHC	145 U
319-86-8	Delta-BHC	100 U
58-89-9	Gamma-BHC (Lindane)	35 U
76-44-8	Heptachlor	15 U
309-00-2	Aldrin	15 U
1024-57-3	Heptachlor Epoxide	60 U
959-98-8	Endosulfan I	45 U
60-57-1	Dieldrin	10 U
72-55-9	4,4'-DDE	30 U
72-20-8	Endrin	25 U
33212-65-9	Endosulfan II	25 U
72-54-8	4,4'-DDD	50 U
1031-07-8	Endosulfan Sulfate	100 U
50-29-3	4,4'-DDT	45 U
72-43-5	Methoxychlor	25 U
53494-70-5	Endrin Ketone	50 U
5103-74-2	Gamma-Chlordane	10 U
5103-71-9	Alpha-Chlordane	20 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1500 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## **\* Pesticide Surrogate Recovery**

Dibutylchlorodate	75%
-------------------	-----

## **Data Qualifiers**

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.



# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 KMS

Matrix: Tissue

VTSR: 09/14/89

Date Extracted: 10/02/89

Date Analyzed: 10/07/89

Conc/Dil Factor: 1:10

Dry Weight: 0.71 g

Sample No.: RF-3

Matrix Spike

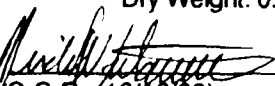
QC Report No.: 3660-Battelle

Project: #60694-AKS

GPC Cleanup: Yes

Alumina Cleanup: Yes

Sulfur Cleanup: No

Data Release Authorized: 

DATA PREPARED: MAC/C C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	160 U
319-85-7	Beta-BHC	145 U
319-86-8	Delta-BHC	100 U
58-89-9	Gamma-BHC (Lindane)	—
76-44-8	Heptachlor	—
309-00-2	Aldrin	—
1024-57-3	Heptachlor Epoxide	60 U
959-98-8	Endosulfan I	45 U
60-57-1	Dieldrin	—
72-55-9	4,4'-DDE	30 U
72-20-8	Endrin	—
33212-65-9	Endosulfan II	25 U
72-54-8	4,4'-DDD	50 U
1031-07-8	Endosulfan Sulfate	100 U
50-29-3	4,4'-DDT	—
72-43-5	Methoxychlor	25 U
53494-70-5	Endrin Ketone	50 U
5103-74-2	Gamma-Chlordane	10 U
5103-71-9	Alpha-Chlordane	20 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1500 U
12672-29-6	Aroclor-1248	1500 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchloroendate	83%
---------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 KMSD

Matrix: Tissue

VTSR: 09/14/89

Date Extracted: 10/02/89

Date Analyzed: 10/07/89

Conc/Dil Factor: 1:10

Dry Weight: 1.01 g

Sample No.: RF-3

Matrix Spike Dupl.

QC Report No.: 3660-Battelle

Project: #60694-AKS

GPC Cleanup: Yes

Alumina Cleanup: Yes

Sulfur Cleanup: No

Data Release Authorized: *[Signature]*

DATA PREPARED: MAC: C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	160 U
319-85-7	Beta-BHC	145 U
319-86-8	Delta-BHC	100 U
58-89-9	Gamma-BHC (Lindane)	---
76-44-8	Heptachlor	---
309-00-2	Aldrin	---
1024-57-3	Heptachlor Epoxide	60 U
959-98-8	Endosulfan I	45 U
60-57-1	Dieldrin	---
72-55-9	4,4'-DDE	30 U
72-20-8	Endrin	---
33212-65-9	Endosulfan II	25 U
72-54-8	4,4'-DDD	50 U
1031-07-8	Endosulfan Sulfate	100 U
50-29-3	4,4'-DDT	---
72-43-5	Methoxychlor	25 U
53494-70-5	Endrin Ketone	50 U
5103-74-2	Gamma-Chlordane	10 U
5103-71-9	Alpha-Chlordane	20 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1500 U
12672-29-6	Aroclor-1248	1500 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	68%
-------------------	-----

## Data Qualifiers

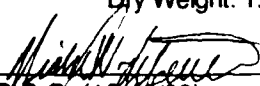
- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 L  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 1.82 g

Sample No.: RF-4  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

Data Release Authorized:   
DATA PREPARED: MAC:C C.G. (10/16/89)

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

CAS Number		µg/kg
319-84-6	Alpha-BHC	135 U
319-85-7	Beta-BHC	100 U
319-86-8	Delta-BHC	60 U
58-89-9	Gamma-BHC (Lindane)	70 U
76-44-8	Heptachlor	10 U
309-00-2	Aldrin	10 U
1024-57-3	Heptachlor Epoxide	50 U
959-98-8	Endosulfan I	45 U
60-57-1	Dieldrin	10 U
72-55-9	4,4'-DDE	35 U
72-20-8	Endrin	40 U
33212-65-9	Endosulfan II	40 U
72-54-8	4,4'-DDD	50 U
1031-07-8	Endosulfan Sulfate	30 U
50-29-3	4,4'-DDT	35 U
72-43-5	Methoxychlor	20 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	10 U
5103-71-9	Alpha-Chlordane	50 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	68%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 M  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.90 g

Sample No.: Ott 7th St.-1  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: 

DATA PREPARED: MAC:C C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	120 U
319-85-7	Beta-BHC	90 U
319-86-8	Delta-BHC	200 U
58-89-9	Gamma-BHC (Lindane)	75 U
76-44-8	Heptachlor	10 U
309-00-2	Aldrin	40 U
1024-57-3	Heptachlor Epoxide	200 U
959-98-8	Endosulfan I	90 U
60-57-1	Dieldrin	50 U
72-55-9	4,4'-DDE	160
72-20-8	Endrin	80 U
33212-65-9	Endosulfan II	10 U
72-54-8	4,4'-DDD	220 U
1031-07-8	Endosulfan Sulfate	75 U
50-29-3	4,4'-DDT	470
72-43-5	Methoxychlor	15 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	25 U
5103-71-9	Alpha-Chlordane	70 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor 1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	67%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 N  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.18 g

Sample No.: Ott 7th St.-2  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: *Michael J. Trott*  
DATA PREPARED: MAC: C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	20 U
319-85-7	Beta-BHC	30 U
319-86-8	Delta-BHC	20 U
58-89-9	Gamma-BHC (Lindane)	30 U
76-44-8	Heptachlor	95 U
309-00-2	Aldrin	90 U
1024-57-3	Heptachlor Epoxide	95 U
959-98-8	Endosulfan I	40 U
60-57-1	Dieldrin	40 U
72-55-9	4,4'-DDE	190
72-20-8	Endrin	45 U
33212-65-9	Endosulfan II	50 U
72-54-8	4,4'-DDD	210
1031-07-8	Endosulfan Sulfate	55 U
50-29-3	4,4'-DDT	480
72-43-5	Methoxychlor	80 U
53494-70-5	Endrin Ketone	55 U
5103-74-2	Gamma-Chlordane	30 U
5103-71-9	Alpha-Chlordane	35 U
8001-35-2	Toxaphene	6000 U
-	Aroclor-1242/1016	6000 U
12672-29-6	Aroclor-1248	6000 U
11097-69-1	Aroclor-1254	6000 U
11096-82-5	Aroclor-1260	6000 U
11104-28-2	Aroclor-1221	6000 U
11141-16-5	Aroclor-1232	6000 U
-	Aroclor-1262	6000 U
-	Aroclor-1268	6000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorendate	65%
--------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 O

Matrix: Tissue

VTSR: 09/14/89

Date Extracted: 10/02/89

Date Analyzed: 10/07/89

Conc/Dil Factor: 1:10

Dry Weight: 0.69 g

Sample No.: Ott 7th St.-3

QC Report No.: 3660-Battelle

Project: #60694-AKS

Data Release Authorized: *[Signature]*

DATA PREPARED: MAC:C C.G. (10/16/89)

GPC Cleanup: Yes

Alumina Cleanup: Yes

Sulfur Cleanup: No

CAS Number		µg/kg
319-84-6	Alpha-BHC	110 U
319-85-7	Beta-BHC	110 U
319-86-8	Delta-BHC	60 U
58-89-9	Gamma-BHC (Lindane)	125 U
76-44-8	Heptachlor	25 U
309-00-2	Aldrin	40 U
1024-57-3	Heptachlor Epoxide	100 U
959-98-8	Endosulfan I	15 U
60-57-1	Dieldrin	60 U
72-55-9	4,4'-DDE	210
72-20-8	Endrin	30 U
33212-65-9	Endosulfan II	30 U
72-54-8	4,4'-DDD	230
1031-07-8	Endosulfan Sulfate	45 U
50-29-3	4,4'-DDT	770
72-43-5	Methoxychlor	20 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	20 U
5103-71-9	Alpha-Chlordane	35 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	73%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 P  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.89 g

Sample No.: Ott 7th St.- 4  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized:   
DATA PREPARED: MAC: C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	135 U
319-85-7	Beta-BHC	75 U
319-86-8	Delta-BHC	100 U
58-89-9	Gamma-BHC (Lindane)	70 U
76-44-8	Heptachlor	20 U
309-00-2	Aldrin	70 U
1024-57-3	Heptachlor Epoxide	150 U
959-98-8	Endosulfan I	55 U
60-57-1	Dieldrin	35 U
72-55-9	4,4'-DDE	180
72-20-8	Endrin	45 U
33212-65-9	Endosulfan II	10 U
72-54-8	4,4'-DDD	270
1031-07-8	Endosulfan Sulfate	23 U
50-29-3	4,4'-DDT	510
72-43-5	Methoxychlor	20 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	15 U
5103-71-9	Alpha-Chlordane	55 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1000 U
12672-29-6	Aroclor-1248	1000 U
11097-69-1	Aroclor-1254	1000 U
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	78%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 Q  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 1.42 g

Sample No.: LS-1  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

Data Release Authorized: *Michael J. Battelle*

DATA PREPARED: MAC: C.C.G. (10/16/89)

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

CAS Number		µg/kg
319-84-6	Alpha-BHC	85 U
319-85-7	Beta-BHC	75 U
319-86-8	Delta-BHC	45 U
58-89-9	Gamma-BHC (Lindane)	45 U
76-44-8	Heptachlor	10 U
309-00-2	Aldrin	65 U
1024-57-3	Heptachlor Epoxide	100 U
959-98-8	Endosulfan I	35 U
60-57-1	Dieldrin	35 U
72-55-9	4,4'-DDE	150 U
72-20-8	Endrin	45 U
33212-65-9	Endosulfan II	60 U
72-54-8	4,4'-DDD	190 U
1031-07-8	Endosulfan Sulfate	23 U
50-29-3	4,4'-DDT	340 U
72-43-5	Methoxychlor	20 U
53494-70-5	Endrin Ketone	60 U
5103-74-2	Gamma-Chlordane	60 U
5103-71-9	Alpha-Chlordane	35 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	1500 U
12672-29-6	Aroclor-1248	1500 U
11097-69-1	Aroclor-1254	2300
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	76%
-------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.



# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 R  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.54 g

Sample No.: LS-2  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: *Michael H. Hatten*  
DATA PREPARED: MAC: C.C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	190 U
319-85-7	Beta-BHC	130 U
319-86-8	Delta-BHC	110 U
58-89-9	Gamma-BHC (Lindane)	65 U
76-44-8	Heptachlor	10 U
309-00-2	Aldrin	100 U
1024-57-3	Heptachlor Epoxide	150 U
959-98-8	Endosulfan I	15 U
60-57-1	Dieldrin	55 U
72-55-9	4,4'-DDE	220 U
72-20-8	Endrin	15 U
33212-65-9	Endosulfan II	15 U
72-54-8	4,4'-DDD	150 U
1031-07-8	Endosulfan Sulfate	90 U
50-29-3	4,4'-DDT	610 U
72-43-5	Methoxychlor	30 U
53494-70-5	Endrin Ketone	20 U
5103-74-2	Gamma-Chlordane	75 U
5103-71-9	Alpha-Chlordane	15 U
8001-35-2	Toxaphene	2000 U
-	Aroclor-1242/1016	2000 U
12672-29-6	Aroclor-1248	2000 U
11097-69-1	Aroclor-1254	2500
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorodate	67 %
-------------------	------

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 S  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.97 g

Sample No.: LS-3  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: 

DATA PREPARED: MAC:C C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	220 U
319-85-7	Beta-BHC	160 U
319-86-8	Delta-BHC	100 U
58-89-9	Gamma-BHC (Lindane)	60 U
76-44-8	Heptachlor	20 U
309-00-2	Aldrin	80 U
1024-57-3	Heptachlor Epoxide	150 U
959-98-8	Endosulfan I	35 U
60-57-1	Dieldrin	80 U
72-55-9	4,4'-DDE	240 U
72-20-8	Endrin	40 U
33212-65-9	Endosulfan II	20 U
72-54-8	4,4'-DDD	150 U
1031-07-8	Endosulfan Sulfate	50 U
50-29-3	4,4'-DDT	560 U
72-43-5	Methoxychlor	15 U
53494-70-5	Endrin Ketone	60 U
5103-74-2	Gamma-Chlordane	85 U
5103-71-9	Alpha-Chlordane	35 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	2000 U
12672-29-6	Aroclor-1248	2000 U
11097-69-1	Aroclor-1254	2700
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchloroendate	74%
---------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 T  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.67 g

Sample No.: LS-4  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: 

DATA PREPARED: MAC/C C.G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	100 U
319-85-7	Beta-BHC	100 U
319-86-8	Delta-BHC	125 U
58-89-9	Gamma-BHC (Lindane)	100 U
76-44-8	Heptachlor	40 U
309-00-2	Aldrin	80 U
1024-57-3	Heptachlor Epoxide	200 U
959-98-8	Endosulfan I	80 U
60-57-1	Dieldrin	40 U
72-55-9	4,4'-DDE	200 U
72-20-8	Endrin	100 U
33212-65-9	Endosulfan II	15 U
72-54-8	4,4'-DDD	320 U
1031-07-8	Endosulfan Sulfate	60 U
50-29-3	4,4'-DDT	280 U
72-43-5	Methoxychlor	25 U
53494-70-5	Endrin Ketone	15 U
5103-74-2	Gamma-Chlordane	40 U
5103-71-9	Alpha-Chlordane	75 U
8001-35-2	Toxaphene	1500 U
-	Aroclor-1242/1016	2000 U
12672-29-6	Aroclor-1248	2000 U
11097-69-1	Aroclor-1254	3000
11096-82-5	Aroclor-1260	1000 U
11104-28-2	Aroclor-1221	1000 U
11141-16-5	Aroclor-1232	1000 U
-	Aroclor-1262	1000 U
-	Aroclor-1268	1000 U

## \* Pesticide Surrogate Recovery

Dibutylchlorendate	74%
--------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.


# ORGANICS ANALYSIS DATA SHEET - PESTICIDE/PCB

Lab Sample ID: 3660 U  
Matrix: Tissue  
VTSR: 09/14/89

Date Extracted: 10/02/89  
Date Analyzed: 10/07/89  
Conc/Dil Factor: 1:10  
Dry Weight: 0.42 g

Sample No.: T O  
QC Report No.: 3660-Battelle  
Project: #60694-AKS

GPC Cleanup: Yes  
Alumina Cleanup: Yes  
Sulfur Cleanup: No

Data Release Authorized: 

DATA PREPARED: MAC: C G. (10/16/89)

CAS Number		µg/kg
319-84-6	Alpha-BHC	85 U
319-85-7	Beta-BHC	60 U
319-86-8	Delta-BHC	70 U
58-89-9	Gamma-BHC (Lindane)	50 U
76-44-8	Heptachlor	30 U
309-00-2	Aldrin	60 U
1024-57-3	Heptachlor Epoxide	120 U
959-98-8	Endosulfan I	80 U
60-57-1	Dieldrin	40 U
72-55-9	4,4'-DDE	130
72-20-8	Endrin	20 U
33212-65-9	Endosulfan II	20 U
72-54-8	4,4'-DDD	112
1031-07-8	Endosulfan Sulfate	90 U
50-29-3	4,4'-DDT	520
72-43-5	Methoxychlor	35 U
53494-70-5	Endrin Ketone	25 U
5103-74-2	Gamma-Chlordane	50 U
5103-71-9	Alpha-Chlordane	40 U
8001-35-2	Toxaphene	3000 U
-	Aroclor-1242/1016	2500 U
12672-29-6	Aroclor-1248	2500 U
11097-69-1	Aroclor-1254	2500 U
11096-82-5	Aroclor-1260	2500 U
11104-28-2	Aroclor-1221	2500 U
11141-16-5	Aroclor-1232	2500 U
-	Aroclor-1262	2500 U
-	Aroclor-1268	2500 U

## \* Pesticide Surrogate Recovery

Dibutylchloroendate	80%
---------------------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.

# TISSUE PESTICIDE MATRIX SPIKE/MATRIX SPIKE DUPLICATE RECOVERY

ARI Sample No: 3660 K  
Client No: RF-3

Client: Battelle  
Project: P.O.#60694AKS

COMPOUND	SPIKE ADDED (µg/kg)	SAMPLE CONC. (µg/kg)	MS CONC. (µg/kg)	MS % REC	QC LIMITS REC
Lindane	280	0	280	100	46-127
Heptachlor	280	0	214	76	35-130
Aldrin	280	0	220	79	34-132
Dieldrin	700	0	560	80	31-134
Endrin	700	0	610	87	42-139
4,4'-DDT	700	0	690	98	23-134

COMPOUND	SPIKE ADDED (µg/kg)	MSD CONC. (µg/kg)	MSD % REC	% RPD	Q C LIMITS	
					RPD	REC
Lindane	200	207	104	3.9	50	46-127
Heptachlor	200	145	73	4.0	31	35-130
Aldrin	200	154	77	2.6	43	34-132
Dieldrin	500	370	74	7.8	38	31-134
Endrin	500	414	83	4.7	45	42-139
4,4'-DDT	500	445	89	9.6	50	23-134

RPD: 0 out of 6 outside limits  
Spike Recovery: 0 out of 12 outside limits

Asterisked values outside QC Limits

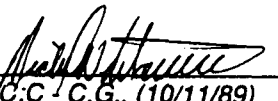
FORM III PEST-1

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 1002MB  
Matrix: Tissue

Date Extracted: 10/02/89  
Date Analyzed: 10/05/89  
Conc/Dil Factor: 1 : 1  
Dry Weight: 1.0 g

Sample No: Method Blank  
QC Report No: 3660-Battelle  
VTSR: 09/14/89

Data Release Authorized:   
REPORT PREPARED: MAC: C. G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	1.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	2.0 U
50-32-8	Benzo(a)Pyrene	2.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	92%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 A

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/05/89

Conc/Dil Factor: 1 : 1

Dry Weight: 1.70 g

Sample No: TI-1

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC:C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	1.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	35 U
50-32-8	Benzo(a)Pyrene	2.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	107%
-----------	------

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 B

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/05/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.70 g

Sample No: TI-2

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC:C C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	2.0 U
120-12-7	Anthracene	2.5 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	1.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	55 U
50-32-8	Benzo(a)Pyrene	2.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	83%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.



ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 C

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/05/89

Conc/Dil Factor: 1 : 1

Dry Weight: 1.04 g

Sample No: TI-3

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized:

REPORT PREPARED: MAC: C C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	1.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	35 U
50-32-8	Benzo(a)Pyrene	2.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

SURROGATE PERCENT RECOVERY

Terphenyl	97%
-----------	-----

Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 D

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/05/89

Conc/Dil Factor: 1 : 1

Dry Weight: 1.19 g

Sample No: TI-4

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC: C - C.G. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	1.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	40 U
50-32-8	Benzo(a)Pyrene	2.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	87%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 E

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/05/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.90 g

Sample No: US-1

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC:C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	15
129-00-0	Pyrene	26
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	7.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	65 U
50-32-8	Benzo(a)Pyrene	5.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	91%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

**ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID**

**Lab Sample ID: 3660 F**  
Matrix: Tissue

Date Extracted: 10/02/89  
Date Analyzed: 10/05/89  
Conc/Dil Factor: 1 : 1  
Dry Weight: 1.01 g

**Sample No: US-2**  
QC Report No: 3660-Battelle  
VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC/C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.5 U
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	23
129-00-0	Pyrene	40
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	13
205-99-2	Benzo(b)Fluoranthene &	140 U
207-08-9	Benzo(k)Fluoranthene	
50-32-8	Benzo(a)Pyrene	14
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

**SURROGATE PERCENT RECOVERY**

Terphenyl	96%
-----------	-----

**Data Qualifiers**

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 G

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/05/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.81 g

Sample No: US-3

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC:C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	2.1
129-00-0	Pyrene	3.8
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	10 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	110 U
50-32-8	Benzo(a)Pyrene	7.5 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

SURROGATE PERCENT RECOVERY

Terphenyl	113%
-----------	------

Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

**ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID**

**Lab Sample ID: 3660 H**

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/05/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.67 g

**Sample No: US-4**

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC:C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	1.2
129-00-0	Pyrene	2.2
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	7.1
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	60 U
50-32-8	Benzo(a)Pyrene	4.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

**SURROGATE PERCENT RECOVERY**

Terphenyl	64%
-----------	-----

**Data Qualifiers**

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 I  
Matrix: Tissue

Date Extracted: 10/02/89  
Date Analyzed: 10/05/89  
Conc/Dil Factor: 1 : 1  
Dry Weight: 2.24 g

Sample No: RF-1  
QC Report No: 3660-Battelle  
VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC/C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	4.0 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	1.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	30 U
50-32-8	Benzo(a)Pyrene	3.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	76%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 J

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/05/89

Conc/Dil Factor: 1 : 1

Dry Weight: 2.17 g

Sample No: RF-2

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC/C-C.G. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	2.5 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	10 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	50 U
50-32-8	Benzo(a)Pyrene	3.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	93%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.



# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 KMS

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/05/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.71 g

Sample No: RF-3

Matrix Spike

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAO:C /C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	—
86-73-7	Fluorene	—
85-01-8	Phenanthrene	6.5
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	—
129-00-0	Pyrene	3.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	55 U
50-32-8	Benzo(a)Pyrene	2.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	90%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 KMSD

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/06/89

Conc/Dil Factor: 1 : 1

Dry Weight: 1.01 g

Sample No: RF-3

Matrix Spike Dupl.

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized:

REPORT PREPARED: MAC:C - C.G.: (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	—
86-73-7	Fluorene	—
85-01-8	Phenanthrene	4.5
120-12-7	Anthracene	1.5 U
206-44-0	Fluoranthene	—
129-00-0	Pyrene	8.5 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	55 U
50-32-8	Benzo(a)Pyrene	2.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

SURROGATE PERCENT RECOVERY

Terphenyl	87%
-----------	-----

Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 M  
Matrix: Tissue

Date Extracted: 10/02/89  
Date Analyzed: 10/06/89  
Conc/Dil Factor: 1 : 1  
Dry Weight: 0.90 g

Sample No: Ott 7th St.-1  
QC Report No: 3660-Battelle  
VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC:C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	2.0 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	1.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	75 U
50-32-8	Benzo(a)Pyrene	3.5 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	91 %
-----------	------

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 N

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/06/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.18 g

Sample No: Ott 7th St.-2

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC: C - C.G. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	5.0 U
208-96-8	Acenaphthylene	5.0 U
83-32-9	Acenaphthene	5.0 U
86-73-7	Fluorene	5.0 U
85-01-8	Phenanthrene	5.0 U
120-12-7	Anthracene	5.0 U
206-44-0	Fluoranthene	5.0 U
129-00-0	Pyrene	5.0 U
56-55-3	Benzo(a)Anthracene	5.0 U
218-01-9	Chrysene	5.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	45 U
50-32-8	Benzo(a)Pyrene	10 U
193-39-5	Indeno(1,2,3-cd)Pyrene	20 U
53-70-3	Dibenz(a,h)Anthracene	20 U
191-24-2	Benzo(ghi)Perylene	20 U

## SURROGATE PERCENT RECOVERY

Terphenyl	75%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 O

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/06/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.69 g

Sample No: Ott 7th St.-3

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC: C - C.G. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	2.5 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	1.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	60 U
50-32-8	Benzo(a)Pyrene	2.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	95%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 P

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/06/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.89 g

Sample No: Ott 7th St.-4

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC: C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	1.5 U
206-44-0	Fluoranthene	1.0 U
129-00-0	Pyrene	1.0 U
56-55-3	Benzo(a)Anthracene	1.0 U
218-01-9	Chrysene	1.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	65 U
50-32-8	Benzo(a)Pyrene	3.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	100%
-----------	------

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 Q

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/06/89

Conc/Dil Factor: 1 : 1

Dry Weight: 1.42 g

Sample No: LS-1

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC: C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	1.0 U
208-96-8	Acenaphthylene	1.0 U
83-32-9	Acenaphthene	1.0 U
86-73-7	Fluorene	1.0 U
85-01-8	Phenanthrene	1.0 U
120-12-7	Anthracene	1.0 U
206-44-0	Fluoranthene	3.3
129-00-0	Pyrene	17
56-55-3	Benzo(a)Anthracene	3.0 U
218-01-9	Chrysene	6.0
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	6.5 U
50-32-8	Benzo(a)Pyrene	4.5 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	95%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 R

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/06/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.54 g

Sample No: LS-2

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC: C - C.G.: (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	2.0 U
208-96-8	Acenaphthylene	2.0 U
83-32-9	Acenaphthene	2.0 U
86-73-7	Fluorene	2.0 U
85-01-8	Phenanthrene	2.0 U
120-12-7	Anthracene	2.0 U
206-44-0	Fluoranthene	3.9
129-00-0	Pyrene	1.5
56-55-3	Benzo(a)Anthracene	3.0 U
218-01-9	Chrysene	6.5
205-99-2	Benzo(b)Fluoranthene & Benzo(k)Fluoranthene	60 U
207-08-9		
50-32-8	Benzo(a)Pyrene	4.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	7.0 U
53-70-3	Dibenz(a,h)Anthracene	7.0 U
191-24-2	Benzo(ghi)Perylene	7.0 U

## SURROGATE PERCENT RECOVERY

Terphenyl	97%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.



# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 S

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/06/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.97 g

Sample No: LS-3

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC:C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	2.0 U
208-96-8	Acenaphthylene	2.0 U
83-32-9	Acenaphthene	2.0 U
86-73-7	Fluorene	2.0 U
85-01-8	Phenanthrene	2.0 U
120-12-7	Anthracene	1.5 U
206-44-0	Fluoranthene	4.7
129-00-0	Pyrene	18
56-55-3	Benzo(a)Anthracene	3.0 U
218-01-9	Chrysene	5.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	80 U
50-32-8	Benzo(a)Pyrene	4.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	3.5 U
53-70-3	Dibenz(a,h)Anthracene	3.5 U
191-24-2	Benzo(ghi)Perylene	3.5 U

## SURROGATE PERCENT RECOVERY

Terphenyl	93%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 T

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/06/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.67 g

Sample No: LS-4

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC/C - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	2.0 U
208-96-8	Acenaphthylene	1.5 U
83-32-9	Acenaphthene	1.5 U
86-73-7	Fluorene	2.0 U
85-01-8	Phenanthrene	2.0 U
120-12-7	Anthracene	2.0 U
206-44-0	Fluoranthene	7.7
129-00-0	Pyrene	2.2
56-55-3	Benzo(a)Anthracene	3.5 U
218-01-9	Chrysene	6.0 U
205-99-2	Benzo(b)Fluoranthene &	75 U
207-08-9	Benzo(k)Fluoranthene	
50-32-8	Benzo(a)Pyrene	5.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	8.0 U
53-70-3	Dibenz(a,h)Anthracene	8.0 U
191-24-2	Benzo(ghi)Perylene	8.0 U

## SURROGATE PERCENT RECOVERY

Terphenyl	94%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

# ORGANICS ANALYSIS DATA SHEET- PNA by GC-FID

Lab Sample ID: 3660 U

Matrix: Tissue

Date Extracted: 10/02/89

Date Analyzed: 10/06/89

Conc/Dil Factor: 1 : 1

Dry Weight: 0.42 g

Sample No: T O

QC Report No: 3660-Battelle

VTSR: 09/14/89

Data Release Authorized: 

REPORT PREPARED: MAC.G - C.G.. (10/11/89)

CAS Number		mg/kg
91-20-3	Naphthalene	2.0 U
208-96-8	Acenaphthylene	2.0 U
83-32-9	Acenaphthene	2.0 U
86-73-7	Fluorene	2.0 U
85-01-8	Phenanthrene	2.0 U
120-12-7	Anthracene	2.0 U
206-44-0	Fluoranthene	2.0 U
129-00-0	Pyrene	2.5 U
56-55-3	Benzo(a)Anthracene	2.0 U
218-01-9	Chrysene	2.0 U
205-99-2	Benzo(b)Fluoranthene &	
207-08-9	Benzo(k)Fluoranthene	45 U
50-32-8	Benzo(a)Pyrene	2.0 U
193-39-5	Indeno(1,2,3-cd)Pyrene	6.0 U
53-70-3	Dibenz(a,h)Anthracene	6.0 U
191-24-2	Benzo(ghi)Perylene	6.0 U

## SURROGATE PERCENT RECOVERY

Terphenyl	92%
-----------	-----

## Data Qualifiers

- U Indicates compound was analyzed for but not detected at the given detection limit.
- J Indicates an estimated value when the result is less than the calculated detection limit.
- NA Indicates compound not analyzed.
- NR Indicates compound not reported due to dilution and/or matrix interference.

**PNA MATRIX SPIKE/MATRIX SPIKE DUPLICATE RECOVERY SUMMARY**

**Client: Battelle**  
**Project: P.O.#60694AKS**  
**VTSR: 09/14/89**

**ARI Sample No: 3660 K**  
**Client Sample No: RF-3**

**Date Analyzed: 031325**  
**Amount Analyzed: 1 Liter**  
**Conc./Dil.: 1 to 1**

<b>COMPOUND</b>	<b>CONC. MS ADDED (mg/kg)</b>	<b>CONC. MSD ADDED (mg/kg)</b>	<b>SAMPLE RESULT CONC. (mg/kg)</b>	<b>MS CONC. (mg/kg)</b>	<b>MS % REC</b>	<b>MSD CONC. (mg/kg)</b>	<b>MSD % REC</b>	<b>RPD</b>
<b>Acenaphthene</b>	140	99	0	99.8	71	67.5	68	4.3
<b>Fluorene</b>	140	99	0	65.8	47	45.3	46	2.2
<b>Fluoranthene</b>	140	99	0	95.3	68	65.6	66	3.0

#### **Waterways Experiment Station Cataloging-in-Publication Data**

Evaluation of upland disposal of Oakland Harbor, California, sediment.  
Volume I: Turning basin sediments / by C.R. Lee ... [et al.] ; prepared for  
US Army Engineer District, San Francisco.

288 p. : ill. ; 28 cm. -- (Miscellaneous paper ; EL-92-12)

Includes bibliographical references.

1. Marine sediments -- California -- Oakland -- Environmental aspects -  
- Evaluation. 2. Dredging spoil -- Environmental aspects -- Evaluation.  
3. Spoil banks -- Leaching. 4. Soil pollution -- California -- Measure-  
ment. I. Lee, Charles R. II. United States. Army. Corps of Engineers.  
San Francisco District. III. U.S. Army Engineer Waterways Experiment  
Station. III. Title: Turning basin sediments. IV. Series: Miscellaneous  
paper (U.S. Army Engineer Waterways Experiment Station) ; EL-92-12.  
TA7 W34m no.EL-92-12